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A

TREATISE

ON

FIELD FORTIFICATION,

AND

OTHER SUBJECTS

CONNECTED WITH THE DUTIES OF THE

FIELD ENGINEER.

Illustrated with Twelve Plates.

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PREFACE.

The Work now submitted to the Public was completed early in 1831, and would have appeared in the course of that year, had not causes beyond the control of the compiler operated to delay its publication until the present period.

The want of a treatise on Field Fortification in the English language, for the instruction of those who desire to obtain commissions in his Majesty's service, is too well known among military men to render any apology necessary for offering to their notice a work on that subject.

The compiler, with the aid of Lieutenant O'Brien, of the Royal Staff Corps, who furnished the Chapter on Military Reconnoissance, and Plates X. XI. and XII., has endeavoured to supply the deficiency above alluded to; and he confidently anticipates, that if this attempt to produce a comprehensive and intelligible treatise be deemed

unsuccessful, it will at least have the effect of stimulating some more competent person to undertake that task; and, consequently, that his labour will not have been uselessly expended.

The Appendix contains a few problems of descriptive geometry, and other matter, forming a preliminary study for those who wish to attain a knowledge of the scientific mode of preparing projects of Fortification. Some details relating to Military Mining, interesting only to the engineer, are also there introduced.

The Drawing for Plate IX., to illustrate the mode of sketching, and representing ground, taught to the officers of the Corps of Royal Engineers, was made by Mr. George Carrington.

Note.—Those dimensions on the Plates which have no marks attached, denote yards; feet are marked ′, inches ″—so, in Figure 1, 4′ 3″ is to be read 4 feet 3 inches.

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SECTION I.

INTRODUCTORY OBSERVATIONS, AND GENERAL OUTLINE OF DETACHED WORKS.

1. FORTIFICATION may be considered as both natural and artificial—rocks, rivers, mountains, &c. being natural fortifications.

Artificial fortification consists in so improving the obstacles presented by nature, or in forming them where wanting, that a given number of men placed in occupation of a fortified position may be enabled to repel the assaults of a superior force. An army during a campaign seldom occupies any particular tract of country but for a short period; the fortifications thrown up for the defence of positions, under such circumstances, are in general hastily executed, with more or less stability, according to the nature of the means available, and the time allowed for their completion; in most cases they are formed of earth only, and are called *Intrenchments.*

2. If an army were not sufficiently powerful to manœuvre with the enemy in the field, the

inferior force would endeavour to interpose impediments to the progress of his adversary, to obtain cover from the effects of his weapons, and to secure the means of using his own with the greatest advantage.

Where no natural obstacles present themselves of which to take advantage, a ditch is dug to impede the enemy's progress, the earth excavated therefrom is formed into a bank or mask, behind which the defenders, no longer exposed to the view of the enemy, are greatly protected from the effects of his weapons, while the form given to the inner side of the mask is such as enables them, when required, to use their own with full effect.

The mass of earth thus thrown up by the defenders for their protection is called a *parapet.**

3. The parapet should always be of sufficient height to screen the defenders from the view of the enemy, whence it follows that on level ground the height A B, Fig. 1, must be nearly 8 feet,† but the thickness, B C, should vary in proportion to the calibre of the projectile the parapet is intended to resist.

To allow for the mean height of a man, the distance of the small terrace, or *banquette,* D E, below the point A, is usually made 4¼ feet—the height over which a man can conveniently fire.

The ramp, E F, conducting to the banquette, has

* *It. para-petto,* guard the breast.

† The works described in this chapter are supposed to be constructed on a plain. See articles 57 and 58 for other reasons why the parapet on a plain should be 8 feet high.

always a base G F equal to twice its height E G, except when the parapet is much more than 8 feet high, and in this case the banquette is ascended by steps, with a rise of 9 inches, and a tread of 1 foot.

The *tread* of the banquette D E, is made 3 feet wide, when the parapet is to be defended by a single rank, having a slope of 2 inches to the rear to carry off the water.

The top A I of the parapet has a *superior slope* so directed, that the defenders when mounted on the banquette may see the exterior edge of the ditch. This slope is a necessary evil — an evil, because the less the inclination of the superior slope the stronger will be the parapet; it should, therefore, never exceed $\frac{1}{4}$; viz. I K should not be more than $\frac{1}{4}$ of A K, and it usually does not exceed $\frac{1}{6}$.

The *interior slope* A D, can seldom in the field be lined with brick or stone, or other material capable of maintaining itself without a slope; a base of from 1 to $1\frac{1}{4}$ feet is therefore given to this slope.

The *exterior slope* I H ought always to be left at the natural slope of the earth; it varies therefore, according to the nature of the ground, in ordinary cases not being much more or less than 45°. The intersection A of the superior and interior slopes is called the *crest*, or *interior crest** of the parapet, that of the superior and exterior slopes being the *exterior crest*.

* *Fr.* Crête intérieure, ligne couvrante, ou ligne de feu.

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The counterscarp is generally made steeper than the escarp, because it has not to support the weight of a parapet.

The slopes of ditches, &c. may be made steeper in temperate than in cold climates, the frost in the latter doing more damage than the rain in the former.

When the covering mass has no banquette or superior slope, it is called an *Epaulment.* The artillery make use of epaulments to cover their guns, and they are sometimes thrown up to protect cavalry from the enemy's fire during the time their active services are not required — as, for instance, when they are supporting the operations of a siege.

4. When works are constructed in a solid and durable manner, and intended to exist many years, they are called *Permanent Fortifications,* whilst those which are only wanted for periods not exceeding one or two campaigns, perhaps only for a few days, are termed *Field Fortifications.* In permanent fortification every means required for rendering the works substantial and perfect is supposed to be provided; while in the field, on

pendicular to the parapet, as in Fig. 2; and when the parapet forms a salient angle, the lines representing the bottom, and top of the counterscarp are made circular, being described from the angle formed by the meeting of the escarp lines as a centre.

When the height of the parapet is greater at one end than at the other, a profile must be constructed at each end, and lines then be drawn joining the corresponding points of each profile. The interior crest of the parapet is always represented by a thick line.

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II.

8. *The ground over which an enemy must pass to approach any point of a fortification should be seen both by the direct and flank fire of the defenders.*

III.

9. *The flanking parts of a field-work should always be within an easy musket range of every part of the lines they flank.* In field fortification, no line of defence should be made more than 180 yards long.

IV.

10. *Every part of the exterior of a fortification should be flanked by some other part*—that the assailants may be seen by the defenders in every step of their attack.

V.

11. *The defence should always be as direct as possible.* The defence is called *direct* when the flanking line is perpendicular to the line flanked; when not perpendicular, it is termed *oblique defence.*

The best arrangement to give any two lines which flank each other, is to make their angle of defence a right angle, or a slightly obtuse angle; for as a soldier, when placed behind a parapet, always fires in a direction nearly perpendicular to that parapet, if the angle of defence were less than a right angle, part of the fire of one flank would be directed on the other, which, if it did not occasion accidents, would at best be a mere waste of

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*Of the Double Redan.**

16. A work composed of two redans, so connected together as to defend each other, is called a *double redan*.

This work consists of two faces, A B, C D, and of two flanks, A E, E C, Fig. 5. The double redan being open at the gorge, ought, like the lunette and redan, to be defended by natural obstacles, or by works in its rear. It is often used to cover a small bridge, in which case its faces are defended by batteries placed on the opposite side of the stream or river.

The flanks E C and E A defend the salient angles A and C; but the ditches, excepting opposite the salients, are no better defended than those of the redan and lunette. When the double redan receives no flank defence from works in its rear, flanks *e f* may be added to the faces, as described in art. 14. Fig. 5 is the plan of a redan of which the salient angles A and C are about $75\frac{1}{2}^{\circ}$.

The angle A E C is a right angle, and it is so made that the two salients may be directly defended by the opposite flanks.

In determining the length of the flanks A E, C E, it is to be observed, that if these lines were made very short, they would of necessity afford only a feeble fire, and also that the men mounted on the banquettes near the re-entering angles are prevented by the adjacent parapet from seeing the

* *Fr.* Bonnet de Prêtre.

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to cover the interior space from the view of the enemy on the neighbouring heights, and also to increase the active defence. In large works, the defenders may rally behind them, and rushing *en masse* upon the assailants, before they have formed in sufficient numbers to render defence unavailing, drive them out, and regain possession of the work.

20. The principal defect of square, or quadrilateral redoubts, is, that they present to the assailant four undefended spaces opposite the angles, so that they may be attacked on four equally favourable points at the same time. This defect may be partly remedied by cutting off the angular points, as in Fig. 3, making these short faces about 6 yards long.

Some authors recommend an indented parapet to obtain fire on the salient angles of works, as in Fig. 8. These indented parapets are, however, so difficult of execution, that they can rarely be applied by the practical engineer: it may also be observed, that the fire lost in front of that part of the face occupied by the indented parapet, is equal to that gained on the salients.

21. In a square redoubt the interior slopes and banquettes occupy 22 feet of the interior space; the side of that space, therefore, is 22 feet less than the side of the square; if then the side of the redoubt were only 22 feet, the whole of the interior space would be occupied by the banquettes and their slopes; but it is necessary that the enclosed work should contain a traverse, unless closed by musket-proof barriers, and also a free space for the accommodation of its garrison: it

follows, therefore, that a square redoubt has an inferior limit, to find which the following data may be assumed:—

Suppose that each man requires three feet lineal of parapet, and 15 superficial feet of the interior space—that the traverse to cover the passage into the work occupies 500 feet of the same space—and that the interior slopes of the opposite parapets, treads, and slopes of the banquettes, make the side of the interior space 22 feet less than that of the crest of the parapet; if then the number of men to defend the redoubt be n, its interior surface should be $15\,n + 500$; and if x be put equal to the side of the redoubt in feet, $4\,x$ will be its perimeter, and $x-22$ the side of the interior space, the area of which will be $(x-22)^2$. To determine x and n we have then the two following equations:—

$$\frac{4\,x}{3}=n \dots\dots\dots\dots\dots\dots (1)$$
$$(x-22)^2-500=15\,n \dots\dots\dots\dots\dots (2)$$

Whence we get $x=64$ feet, and $n=85$ men. The smallest square redoubt should, therefore, have a side of 64 feet, and contain a garrison of 85 men.

If the redoubt be defended by two ranks, the banquettes must be made $1\frac{1}{2}$ feet wider, and the solving equations will be—

$$\frac{8\,x}{3}=n \dots\dots\dots\dots\dots\dots\dots (1)$$
$$(x-25)^2-500=15\,n \dots\dots\dots\dots\dots\dots (2)$$

Whence we obtain $x=88$ feet, and $n=234$ men.

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33. In the plan of the bastioned fort given in Fig. 12 there is no point in front of A B which does not appear to be effectually seen; and if the dimensions of the front are not too small, the height of the parapets will not prevent the men arming the parapet G E seeing the bottom of the ditch from D to H, and those on F H from seeing the part G D of that ditch. These parapets will still better defend the ditches in front of A E and B F; so that in the ditch, as well as externally, there is no part which cannot be seen.

The reason why C D is made less in a square fort than in a pentagon is, that if it were made $\frac{1}{7}$ of A B, the angles A and B of the square fort would then be less than 60°.

The lines E G and F H are made perpendicular to B G and A H, to obtain a direct defence for the salient angles.

34. The line A B Fig. 12, is called the *exterior side of the polygon*, or simply the *exterior side*.

C D is *the perpendicular*.

A H and B G the *lines of defence*.

A E and B F the *faces*.

E G and F H the *flanks*.

G H the *curtain*.

The angles have also their particular names:

capitals of the bastions, and consequently support the covered way and places of arms opposite those bastions; that when made sufficiently salient (as in modern fortifications) they place the bastion in a deep re-entering angle, rendering it necessary to take two ravelins before the covered way of the body of the place can be crowned.

A and B are the *salient or flanked angles.*

E and F the *angles of the shoulder.*

G and H the *angles of the flanks.*

35. It now remains to determine what ought to be the length of the exterior side AB.

This length should not be less than 100, or much more than 220 yards, a difference which gives great latitude, and renders the trace of the bastioned fort applicable to many situations.

It would appear, that since the bastioned trace is superior to any other, it should be employed in preference to that of the star or demi-bastioned fort; but in the limits within which those forts can be constructed, viz. with less than 100 yards exterior side, the bastioned front would not contain a sufficient internal space; the ditch towards the middle of the curtain would no longer be seen by the flanks, on account of the necessary height of the parapet above the bottom of that ditch; the flanks would be so short that the greater part of them would be occupied by the parapet of the curtain, and consequently the advantage of reciprocal defence, obtained by breaking the exterior side into faces, flanks, and a curtain, would in a great measure be destroyed. The minimum thus accounted for is only applicable when the crest of the parapet of the fort is not more than 8 feet above the natural level of the ground. If it were necessary to make the parapet much higher, the exterior side of the fort must be increased, otherwise the flanks would not see the bottom of the ditch opposite the centre of the curtain.

The maximum is determined by the range of the musket. It is evident, that as the flank H F ought to defend the salient A, it should be within a moderate range of it, or at a distance of not more than 180 yards. With the superior limit fixed at 220 yards, the line of defence A H is about 175 yards long; a length it would rarely be proper to exceed, because the enemy advancing on the capital of the bastion should be exposed to the fire of the flanks, before he arrives at the counterscarp.

36. Bastioned forts ought only to be employed for important posts, where they may serve as depôts and rallying points for a retreating army. Forts of the above description should therefore be constructed in the most solid and durable manner; and every means should be employed to render them of a sufficiently formidable character, to oblige the enemy to cannonade them with heavy artillery or howitzers, before he can venture to give the assault.

SECTION II.

THE TRACE OR OUTLINE OF FIELD-WORKS CONSIDERED IN COMBINATION WITH EACH OTHER.

37. In the first Section the different independent works used in the field have been treated of. We will now consider them in combination, not noticing their height or relief, but only their horizontal projection or plan.

When several works are so combined that they

defend one another, they are called *Lines*, and are distinguished according to their arrangement, either as *Continued Lines*, or *Lines with Intervals*, and according to their object, as *Intrenched Camps*, *Lines of Contravallation*, *Lines of Circumvallation*, and *Intrenched Positions*.

Of Continued Lines.

38. Continued lines are often used to enclose the suburbs of a fortress, or to connect two strongly intrenched points: they are principally applicable to situations where it is proposed to act on the defensive only, and where they are of so small extent that the whole line of parapet can be occupied with troops exclusive of the reserves: as, for instance, to close a pass between scarped mountains, or on the sea-shore, or on the banks of large rivers; thus resting on natural obstacles, which will prevent their flanks being turned. They are often introduced as portions of an extended line with intervals.

Continued lines were formerly used as siege lines — *i. e.* to blockade a town; but in late wars they have only been introduced for this purpose when large portions of the place being covered by marshes or inundations, the occupation of the intervening necks of land with continued lines became comparatively a work of small labour.

39. Any very extensive continued lines can make but slight resistance as compared with the labour necessarily expended on them, for the enemy may menace several points at the same time;

whence it evidently follows, that nearly as many troops would be required for the defence as are employed in the attack, and then the first principle of fortification fails. Even if the defenders have a sufficient number of disposable troops, they always act under a disadvantage; they must watch and follow every movement of the enemy, and be prepared to resist all his attacks whether real or feigned. In continued lines it has often happened, that while the defenders were concentrating their forces to resist a false attack, the enemy has penetrated at another point where he was not expected; and a continued line once entered may generally be deemed irrecoverably lost.

40. It may here be remarked that lines, and indeed fortifications generally, should only be considered as accessories: the troops are always the principal defence—the intrenchments merely offer them the means of using their weapons with the greatest advantage, affording them cover from the enemy's fire, whilst he must in the attack be exposed to theirs; hence every obstacle that will detain him under the fire of the intrenchment must tend to ensure his defeat.

The most simple outline for a continued line is the following one, invariably used by the celebrated Vauban.

Of Redan Lines.

41. Vauban strengthened the continued line with redans placed 260 yards apart, having 30 yds. of demi-gorge, and 44 yds. of capital Fig. 13.

This outline of Vauban's is defective, inasmuch as the angles B and C are only obliquely defended by the fire of the curtain A D, or by that of the neighbouring redans, which being placed at a long musket-range apart, would very ill defend each other.

When a portion of a frontier is covered by a continued line, narrow passages are left at convenient distances for the ordinary communication with the exterior.

42. If a continued line were never required except to close an extensive frontier, the redan line would be sufficient for the purpose; but it often happens that the same lines are intended both to cut off the communication with the exterior, except by particular routes, and to resist a powerful attack.

Though the trace of all lines must of necessity be adapted to the ground occupied by them, yet it is necessary that the student should be acquainted with various modes of tracing lines, and with their advantages and defects; at the same time it should be remarked, that the improved outlines have a more extended parapet, and consequently require a greater force to defend them, while the labour of throwing them up is proportionably increased.

43. The first modification which presents itself to render Vauban's trace capable of making a better resistance, is to place the redans at 200 yards apart; then the salients will be within musket-range of the lines which flank them.

*Of Continued Redan Lines.**

44. A second method of correcting Vauban's line is to break the curtain B D, Fig. 14, forming a redan B C D, very open at the summit, preserving always between the points A and E the distance of 260 yards. This line, though better in some respects than that of Vauban, is far from being perfect. The three angles, A, C, and E, having an equal external projection, are equally exposed to attack, and this is a great disadvantage. The re-entering angles, B and D, of this outline are dead angles, which is not the case with the re-entering angles A and D, Fig. 13.

In another point of view Vauban's line would be better than a continued redan line, since it presents fewer points of attack, and the parapet from A to D, Fig. 13, cannot be enfiladed.

The salients are the points of attack, because the prolongations of the lines forming the salient angles can easily be taken up by the enemy's artillery; and if those salient points be properly occupied and advantageously situated, an enemy cannot neglect them without exposing himself to be taken in flank or reverse.

To reduce the number of points of attack in a continued redan line, the salient of the large redan may be placed more in advance, giving to its faces the directions B C and D C, Fig. 15, nearly perpendicular to the lines A B and D E, to which lines

* *Fr.* Lignes à queue d'hironde.

a more oblique direction should be given than in the former tracing. Then only two points of attack, C, F, are presented within the extent of 260 yards, and these salients would be well defended by the fire of the flanks A B, D E, &c.

*Of the Tenaille Line.**

45. The tenaille line differs from the continued redan line only in giving greater saliency and gorge to the redans, and making them all equal. The defects remarked in the preceding tracing are also observable in this one, the three angles, A, B, and C, Fig. 16, having equal projection, are equally assailable; but in the tenaille line the three points of attack extend 400 yards, while in the continued redan line they occupy 200 only. Another and a greater defect common to all the outlines yet given, except Vauban's, is, that they present long branches to the enfilade fire of the enemy; who, if he attacked lines traced as already described, might place his guns on the prolongations of the long branches, and by ricochet fire not only destroy the artillery and palisading, but also drive away the infantry from the parapets; he would then advance in columns on the capitals. If the ditch were deep he would throw in fascines enough to enable him to get into it; and when there he would be sheltered from the fire of the parapet. It is because all the faces can be enfiladed with

* *Fr.* Ligne tenaillée.

equal facility, that the tenaille line appears to be the worst for an open country.

*Of Indented Lines.**

46. The indented line is composed of faces, AB, and flanks, BC, perpendicular to one another, Fig. 17. The defects of the indented line are, that all its flanks can be enfiladed, unless directed on parts inaccessible to the enemy, and that their shortness prevents an enemy being seen by them, until he has arrived close to the counterscarp of the long branches.

The indented line may be usefully employed in uniting two principal works, A and B, Fig. 18, placed at too great a distance effectually to defend the whole of the intervening space.

Then on the centre, C, the indented line should change its direction, that is, on one half of the line the flanks should fire from right to left, on the other, the reverse; a cross-fire is thus obtained on the centre, sufficient to defend it if the works A and B were placed at too great a distance for that purpose. It may be well to observe, however, that the whole of the space between the works A and B should be within the range of the artillery of those works, and that not fewer than three pieces of ordnance should be placed in each of them, to flank the approach to the indented line.

* *Fr.* Ligne en crémaillère.

Of the Bastioned Redan Line.

47. When only a small length of continued line is required, the best method of tracing it is shewn in Fig. 19; for if lines of great extent are to be thrown up, the most simple outline should be adopted. The faces C M, C N are made equal to A G or B H, and the flanks G *g*, M *m* are perpendicular to the lines of defence. The outline of bastioned redans has in some respects an advantage over the common bastioned system; for if two fronts were traced, as in art. 31, on the lines A C and B C, the redans will be found to be of greater capacity than the bastions, and the flank M *m* to be longer in the first than in the second case; which is desirable, because that flank has to defend the point of attack; and, on the contrary, the flank G *g* of the redans will be shorter than that of the bastions, which is also convenient, for its fire is directed on a part but little exposed.

The trace of bastioned redans is, then, on level ground one of the best that can be adopted.

If applied to an irregular site, which can seldom be done, A B must be divided into 40 parts. Then A D, B E, and I C, are each made equal to five; D P and E Q, to three; D G and A H, to six of those parts. The side A B should not be less than 300, or more than 500 yards in length.

48. The preceding outline, that of the indented line, connecting two principal works, and of continued redans, with the modification made thereon, possess the advantage of being assailable only on

salients placed at considerable distances, and which, being few in number, can be the better guarded when the number of the troops is small.

In the construction of the work these parts may be particularly attended to, and strengthened by every method employed in the field; and of which descriptions will be given in other parts of this treatise.

The advantage above noticed is so important, that we may prescribe as a general rule, that works of great extent should always present strongly marked salient points.

49. One of the least objectionable modes of tracing a continued line would be to occupy the principal points with redoubts, with lines of communication between them, of the same profile as the parallels formed in siege operations, Fig. 152, &c.

50. When lines are of a polygonal form, the salient angles made by the sides of the great polygon are the weak points, to which attention should be principally directed. When the angle is obtuse, flanks, A and B, Fig. 20, may be traced either in the form of redans or demi-bastions; but if the angle be acute, as in Fig. 21, then give it the form A B C, flanked by E and F.

Instead of forming a tenaille at the acute angle, when the point is one of importance, the angle may be cut off by a bastioned front, as in Fig. 22, and, if required, the point O may be occupied either with a lunette or a ravelin flanked by the works in its rear. The salients A and B of the

bastioned front should extend a sufficient distance beyond the prolongations O M and O N of the faces of the lunette or ravelin to defend its ditches; which should therefore be made to terminate towards the ends of the flanks, in slopes directed on the faces of the demi-bastions in their rear.

No fixed dimensions can be given for works of this description; they must vary in proportion to the opening of the angle O, and the extent of the ground to be occupied.

SECTION III.

OF LINES WITH INTERVALS.

51. Lines composed of detached works placed at such distances as to derive protection from one another, and which, being few in number, can be solidly constructed, offer points of security behind which you can remain in a menacing posture, ready to rush in mass upon the enemy whenever a favourable opportunity offers. They oblige him, if he cannot turn your position, either to attack you on the field of battle you have selected and prepared, or to remain inactive.

In such cases, it is to that army which is best provided with the means of remaining in repose, but is ever ready to take advantage of any false or retrograde movement of the adversary, that success will probably fall. As an instance, the Anglo-Portuguese army in the lines of Lisbon remained a

whole winter supplied with provisions from that city. The French army, comparatively destitute of supplies, finding the position too formidable to attack, retreated to take up a position where their left flank rested on the Tagus, and their front was covered by marshes and inundations; they were thus enabled to detach large parties to collect provisions and forage, and still have their position so occupied as not to risk much if forced to a general engagement.

These advantages continued lines do not possess, for they are nearly as great an impediment to your offensive operations, as they are to those of the enemy.

52. In a line with intervals the redoubts or enclosed works may be garrisoned by militia or other inferior troops, who, though comparatively useless in the field, will fight behind a parapet, the approach to which is defended by a ditch and palisade.

The columns of troops may then advance through the intervals, to attack, pursue, or annoy the enemy at pleasure, and thus preserve in the defence all the moral advantages of an attack—advantages resulting from the opinion soldiers entertain of their own superiority when they assail an enemy, or manœuvre boldly in his presence.

53. The following is commonly proposed as a good method of tracing lines with intervals. Upon a first line, generally forming a portion of a polygon or curve, the salients, A, B, C (Fig. 23), of lunettes are placed, at from 300 to 500 yards apart;

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These advantages continued lines do not possess, for they are nearly as great an impediment to your offensive operations, as they are to those of the enemy.

52. In a line with intervals the redoubts or enclosed works may be garrisoned by militia or other inferior troops, who, though comparatively useless in the field, will fight behind a parapet, the approach to which is defended by a ditch and palisade.

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able positions outside of the works. If the redoubts D and E are armed with artillery, the enemy will direct his fire on them; the parapets of the redoubts should be strengthened accordingly; and that the prolongations of their faces may not easily be taken up, they should be directed on the salients A, B, and C of the lunettes.

54. Although the lunettes are not intended to be constantly armed with artillery, barbettes (art. 85) should be constructed at the salient angles, to be occupied as occasion may require by the field-batteries.

If the line consisted of two rows of redoubts, so placed as to defend each other, the rear parapets of the advanced redoubts should not be made more than from four to six feet thick, in order that they may be easily destroyed by the guns in the second line of redoubts, when their capture renders such a measure necessary.

Lines with intervals sometimes consist of detached redoubts or forts placed at the salient and commanding points of a position, either singly or otherwise, according to the importance and extent of the part to be defended.

When a position is occupied in this manner, the works should be sufficiently near each other to prevent the enemy passing between them without exposing himself to the effective fire of the artillery in the redoubts, which should therefore not be more th[illegible]s apart.

They shou[illegible]rful garrisons, and eas[illegible]ar, otherwise the

enemy might neglect them. The spaces between the large works, or clusters of redoubts, would then be occupied by the moveable columns of infantry and cavalry, from which the garrisons of the works would receive reinforcements, ammunition, or other required assistance.

In bold and rocky positions, many portions of a line may, with comparatively little labour, be rendered nearly or wholly inaccessible by scarping the slopes, in doing which, great care must be taken that the base of the parts cut down may not form a road or resting-place, of which the enemy might avail himself.

55. An advantageous and economical mode of tracing a line with intervals, when thrown up in a level country, is to suppress the second line of redoubts, and replace them by central works, sweeping with their fire the intervals and interiors of the lunettes.

Upon an arc of about 900 yards' radius, and which may be taken by estimation on the ground, the salients A, Fig. 24, of lunettes, are placed 300 yards apart.

In the centre O of the radius A C, a central work should be constructed, such as a polygonal redoubt or star-fort, to contain heavy ordnance.

The flanks D of the line must be strongly supported by works, or natural obstacles, that the enemy may not be able to turn the position. The redoubts D on the flanks should have slight parapets towards the central work, that they may, if required, be easily destroyed by its artillery.

At the points of junction of the lines of defence, epaulments, P, cover the field artillery, placed there to flank the faces of the lunettes, A. These epaulments should only be 3½ feet high, that the guns may fire over them; their construction would, therefore, be a work of small labour, yet they will be of great assistance. In this arrangement of lines with intervals, the interior of the lunettes is well defended by the central work, on which the principal labour and care should be bestowed, this being the main point.

56. If the position be more than 1800 yards in extent, it would be necessary to have two or more arcs similar to the one already described, supported in the rear by a bastioned fort, or by polygonal redoubts.

Works of small importance, such as redans for instance, should be thrown up in the re-entering angles formed by the meeting of the arcs, these points being strong in themselves. It must be evident that the tracing above described for lines with intervals, can only be applied to fields of battle prepared at leisure, and that the localities may make it vary infinitely; but it is the spirit of the arrangement, rather than the arrangement itself, which it is in all cases desirable to seize, that we may not err against principles when compelled by local circumstances to depart from regular forms.

CHAPTER II.

ON THE RELIEF AND COMMAND OF FIELD-WORKS.

57. The *relief* of a work is the height of its interior crest above the bottom of the ditch; the *command*, its height above the ground, if constructed on a plain, or above the plane of site if on an irregular surface.

The command of a parapet on level ground, intended to cover the troops behind it from the enemy's fire, ought not to be less than 6½ feet; and this height is only applicable to unimportant works.

If only 6½ feet of command were given to the parapet, the men mounted on the banquettes of the rear faces of a work would not be covered from the view of the enemy, unless the interior space were of great width.

This consideration has induced engineers to prescribe 8 feet as the command for ordinary intrenchments.

However considerable this command may appear for field-works, it is not sufficient in all cases to protect the men mounted on the banquettes from *enfilade*, *slant*,* or *reverse fire*. It may here be proper to define the terms just used.

* *Fr.* Écharpe.

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Number of Profile.	Known Quantities.			Width of Ditches.							
	Height of Parapet.	Thickness of Parapet.	Depth of Ditch.	Escarp is at $\frac{1}{3}$, and Counterscarp at $\frac{1}{4}$.		Escarp at $\frac{1}{3}$, Counterscarp $\frac{1}{3}$.		Escarp 45°, Counterscarp $\frac{1}{3}$.		Escarp and Counterscarp 45°.	
	Feet.	Feet.	Feet.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1	$6\frac{1}{2}$	6	8	10	5	11	5	*14	1	*16	1
2	...	9	9	11	3	12	3	*15	2	*17	6
3	...	14	10	12	3	13	7	*16	9	*19	4
4	8	6	12	11	7	13	7	*17	1	*19	8
5	...	9	...	13	0	14	5	18	5	*21	3
6	...	14	...	14	10	16	4	20	4	*23	4
7	9	6	...	14	5	16	0	20	0	*22	10
8	...	9	...	16	0	17	5	21	5	24	5
9	...	14	...	18	2	19	8	23	8	26	8
10	10	6	...	19	0	20	5	24	5	27	5
11	...	9	...	20	9	22	3	26	3	29	3
12	...	14	...	23	7	25	1	29	1	32	1
13	11	6	...	24	11	26	5	30	5	33	5
14	...	9	...	26	11	28	5	32	5	35	5
15	...	14	...	30	1	31	7	35	7	38	7
16	12	6	...	32	5	33	11	37	11	40	11
17	...	9	...	34	8	36	2	40	2	43	2
18	...	14	...	38	2	39	8	43	8	46	8

61. The width of the ditch may also be determined in the following manner. Divide the surface S of the profile of the parapet by the depth of the ditch, and this will give the width at the top: for instance, if the area of the parapet be 108 superficial feet, and the ditch is to be 6 feet deep,

it must be 18 feet wide. This calculation supposes the ditch to be excavated perpendicularly, that the volume of the excavation is not increased, and that the distance traversed by the centres of gravity of the parapet and ditch are equal, none of which suppositions are correct; but it will be found that the slopes of the ditch when at $\frac{1}{3}$ are very nearly equivalent to the increase of volume of the excavation and greater development of the ditch, and that this rule will be sufficiently near the truth for practice.

62. Although we have supposed the parapets not to be less than $6\frac{1}{2}$ feet high, when constructed on a plain, yet, in works of small importance, not required to cover any space in their rear, a less command may be given; but in no case should the command of a parapet be less than 5 feet; and then it would be necessary to lower the berm, in order that the enemy when on it might not see into the interior of the intrenchment.

The means of execution commonly available in the field, together with the great increase of labour consequent on the formation of parapets more than 8 feet high, necessarily prescribe a limit to that height, which on ordinary occasions should not be passed: this limit may be assumed at 12 feet.

In all works of slight profile the escarp and counterscarp should be carried down to meet in a point, and unless means of securing these slopes are provided, or they are left at the natural slope of the ground, the ditch can seldom be made more

than 12 feet deep without endangering the stability of the work.

When parapets are made of more than common height, the superior slopes cannot be directed on the edge of the counterscarp; a glacis, Fig. 25, should then be formed in front of the counterscarp, the crest of which must be kept at least $5\frac{1}{2}$ feet below that of the parapet.

In this case, also, the banquette should be ascended by steps, both to diminish as much as possible the quantity of excavation, and not to occupy too great a portion of the interior space.

The rise of each step should be from 9 inches to 1 foot, the treads from 1 to $1\frac{1}{2}$ feet wide, with an inclination towards the interior of the work to carry off the water.

CHAPTER III.

SECTION I.

DETAILS OF CONSTRUCTION.

Profiling.

63. Having given a general description of the plan and profile of such works as are commonly used in the field, the details of construction remain to be pointed out.

When a work is traced on the ground, *i. e.* after strong pickets have been driven at all the angles, and the lines joining them have been distinctly marked with a pick-axe, two profiles should be set up on each line to shew the workmen the form of the parapet, and to guide them in the execution of their task.

On long faces three or more profiles should be set up. These profiles, when made with straight slips of deal or other wood, shew with great accuracy the form of the parapet, &c. To set up a profile, first drive two square-headed pickets A,B, Fig. 26, marking the width of the parapet; then nail firmly to A an upright slip AC, equal in length to the height of the parapet, and at B set up a piece of indefinite length; nail a slip CD at C, and with a level give it the proper slope of the ; saw off the over-lengths of BD and CD,

and place D E at an angle of 45°. The banquette is similarly treated, as shewn in the Figure.*

64. If profiles are set up shewing the several angles formed by the parapet, they will be of great assistance to the workmen.

To put up oblique profiles, first set up two profiles perpendicular to the parapet of each face, then determine on the angle the point in which the projections of the exterior crest meet, which may be done by tracing, with tapes or lines, parallels to the interior crest previously marked on the ground with the pick-axe. At this point set up a slip or pole of indefinite length, and at the angle of the interior crests, one to shew the height of the crest of the parapet; nail a slip of deal to the top of this last upright, and move it up and down on the other until you find it in the same plane with those shewing the superior slopes in the perpendicular profiles; do the same for the exterior slope, and the banquette.

When slips of deal cannot be readily procured, drive in rough stakes to mark the several heights of the profiles, and stretch a piece of cord from one to another to shew the slopes. If the above assistance cannot be procured to regulate the height of the parapet, it rarely would be necessary to model it accurately; the object is to procure

* The field-service level, invented by Colonel Pasley, R.E., will enable an officer to determine immediately any slope the base of which is a fractional part of, or equal to, its height; whether the slope be measured from a horizontal or vertical line.

cover, and this may be done without the aid of profiles. Having set up the profiles, trace with a pick-axe* the escarp and counterscarp lines.

The width of the berm must depend on the nature of the ground on which the work is constructed; in marshy soil it might be necessary to have a berm of 6 fect, or more, while, on the contrary, in a stiff clay no berm would be required.

65. Though the ditch, when of uniform width, supplies a superabundance of earth at the salient, and too small a quantity at the re-entering angles, yet in field-works this is a matter undeserving of notice; it may not, however, be unnecessary to remark, that it is better to trace the ditch too narrow than too wide; then, if little time be allowed for its excavation, you obtain a ditch of greater depth, while it can at any time be widened if required.

66. In the field an officer has not always time to set up profiles before the workmen arrive; in which case he determines quickly the general outline of the work by angle pickets; and having marked nearly the position of the middle of the ditch, places the workmen there, directing them to what width and depth they are in the first instance to excavate. In the mean time he sets up profiles, and traces the lines of the escarp and counterscarp as before directed.

67. The tracing of the counterscarp in the bastioned front requires some particular details.

* Termed "spit-locking."

It is done in two ways, either making it follow the sinuosities of the parapet, as in Fig. 27, or the counterscarps of the two faces are continued in right lines, meeting opposite the centre of the curtain, as in Fig. 28; then all the space between the flanks and curtain is excavated, which being a work of great labour, this method of executing it could rarely be adopted. In Fig. 27 a portion of the ditch of the face near each shoulder is undefended by the musketry of the parapet.

To remedy this defect, the ditches of the faces may be produced in the form of ramps, Fig. 29, their slopes so directed as to expose the ditch in front of the angles of the shoulder, to the view of the opposite flank.

This arrangement is advantageous also, because it supplies the earth which would otherwise be wanting at the angles of the flank, where the content of the parapet is much greater than that of the ditch.

It might be feared that these ramps would weaken the work, by facilitating the enemy's descent into the ditch; but in field-works the depth of the ditches is not usually sufficient to prevent the enemy leaping into them, so that whether these ramps exist or not, is of little consequence.

Division of Labour.

68. The arrangement of workmen in such a manner that they may not incommode each other, and that the work may proceed with regularity, is a very essential matter. The following methods

are recommended:—Divide the working party into squads of six men each, one with a pick-axe, one with a shovel and rammer, the remainder each with a shovel: the pick-axe with a shovel on each side is placed in the ditch, two shovels on the berm, the shovel and rammer on the parapet; each squad occupying 10 feet lineal, measured on the line of the centre of the ditch. A second method is to divide the ditch into rectangles 3 feet wide, extending in length across the ditch; sixteen men will then be required for every 24 feet lineal of the ditch—eight with a pick-axe and shovel each, four with a shovel and rammer each, and four with shovels only. The first eight excavate the rectangles, as marked in Fig. 30, the odd numbers commencing at the berm, and the even ones in the middle of the ditch, all working towards the counterscarp; and when the even numbers arrive there, they return and begin at the berm. Four shovels are placed on the berm, each occupying 6 feet lineal of it, and the remaining 4 shovels and rammers on the parapet, spreading and ramming the earth. If the parapets were only to be 6 or 9 feet thick, two men on the berm and two on the parapet would be sufficient. A third method, is to divide the ditch into rectangles as before, 6 feet wide each; then place three men to each rectangle, one with a shovel and rammer on the parapet, the second with a pick-axe and shovel excavates from the berm towards the counterscarp, and the third excavates the part of the rectangle next to the counterscarp, heaping the earth on a ridge left for

that purpose, between him and the other man working in the same rectangle.

By the first method 140 men are required for 80 yards lineal of the ditch; by the second, 160 or 140, in proportion to the thickness of the parapet; by the third, 120 men.

In addition to the above working party, sappers, or other intelligent men, are employed in forming the revetments, laying platforms, building powder magazines, &c.

69. The ditch is excavated in layers of 3 feet in depth, steps being left with a rise of 18 inches each, to facilitate the ingress and egress of the workmen, and of such a width that their re-entering angles may coincide with the slopes of the escarp or counterscarp, Fig. 25.

When the ditch is excavated to the required depth, the steps are first cut down with a pick-axe, and the slopes are then dressed with a shovel, if neatness of appearance be desired.

Care should be taken to preserve the good earth to form the slopes of the parapet. For this purpose, fat earth mixed with strong sand is the best.

When works are hastily thrown up, the vegetable mould, which is generally the best for forming the slopes, is covered by the inferior strata: when these latter are, as is often the case, full of small stones, the earth first excavated should be thrown into the interior of the work, to be afterwards used as a cover for the parapet. If this precaution were not taken, many casualties

might occur, from the effect produced by the enemy's shot striking on the stony surface of the parapet.

In selecting the site of a work, rocky situations but slightly covered with earth should be avoided.

70. From the commencement of the work attention should be paid to the draining of its interior, which otherwise might soon be overflowed. When the work is open at the gorge, a small trench may be formed at the lowest part of it, and the terreplein be sloped towards the trench and gorge. In enclosed works, a drain covered with flat stones or wood should be made, to convey the water from the lowest point of the interior into the ditch, taking care to prolong this species of tunnel with planks or other means beyond the base of the escarp, so that the water may not wear away that slope. A couple of planks may be nailed together to form a gutter, which can be let iuto the escarp slope, and the drain be made to empty itself into the gutter, the bottom of which should rest on a few flat stones or ends of fascines. When practicable, the ditches of field-works should also be drained from partial floods, otherwise the escarp and counterscarp slopes will not stand long, unless they are revetted.

71. In all cases work should be given either by task, or at a certain sum per cubic yard of excavation, &c., for men will do much more when tasked than when paid by the day. If peasantry are employed, it is much better and cheaper to pay

a high price for measured work, than to employ them by the day.

As soon as the price is fixed you are at ease; for then the work will certainly be done quickly, and you have only to superintend its execution, and see that it is done properly. It is always necessary to bear in mind, that task-work will be ill done unless the workmen are well looked after; because it is their interest to finish it quickly.

To fix the price of labour, employ a few good workmen, pay them well, and see how much they can do in a given time: you may then calculate what would be a fair remuneration, and make your bargain accordingly. In favourable soil, an expert workman can excavate from 8 to 10 cubic yards in a day of eight hours' work; but this is only when the excavation is near the surface, and the earth is thrown at once on the parapet. When the excavation becomes deeper, or the earth is gravelly and hard, from 6 to 8 cubic yards is as much as can be expected from each workman; and consequently only 4 or 5 cubic yards per man when a relay is placed on the berm. When near the surface in soil requiring the use of a pick-axe, 6 cubic yards would be a fair task for soldiers, who are little accustomed to the use of the pick-axe and shovel.

72. In calculating the time required to throw up an intrenchment, the following additional data may be assumed:—In light, dry, sandy soil, that can be easily dug without the aid of a pick-axe, a man can, in a day of eight hours, load from 19 to

20 cubic yards of earth on barrows. If a pick-axe be required, two men can do the same quantity of work.

If the whole mass must be first moved with a pick-axe, three or four men should be allowed.

A man can also wheel 20 cubic yards of earth per day, to a distance of 30 yards on level ground, or 20 yards on a ramp. Twenty cubic yards of earth will fill 500 wheel-barrows. A horse can do as much work as seven men: he can carry 300 lbs. 20 miles per day, or 200 lbs. 30 miles; he can draw 1600 lbs. on a plain, and from 12 to 1300 lbs. on irregular ground, when the roads are in good order.

SECTION II.

OF REVETMENTS.

Parapet Revetments.

73. It has been stated, that a base of one foot only should be given to the interior slope of the parapet. Earth freshly dug up will seldom stand at this slope; it must therefore be supported with a *revetment*, which is commonly made with fascines, hurdles, sods, planks, casks, gabions, or sand-bags.

Fascine Revetments.

74. The fascines for a revetment should be strong and well bound. When small brushwood is used, they are made 6 feet long and 7 inches

in diameter, firmly bound with 4 or 5 withes or gads, one in the middle, one at each end, and one in each interval. The gads are made of tough twigs, first twisted until the fibres separate, the smaller end is then turned round, so as to form a loop or noose, as in Fig. 31. To make a fascine 6 feet long, the workmen set up three fascine horses on the same level, and in a right line. The fascine horse is formed with two pickets, 5 feet long each, driven about 1 foot obliquely into the ground, so as to cross each other at right angles 2 feet above the surface of the earth, as in Fig. 32, and fastened together at their point of meeting with cord or gads. The brushwood, stripped of all its leaves and smaller branches, and which should be from ½ inch to 1 inch in diameter, and 5 or 6 feet long, is then laid on the fascine horses, the thick ends being placed alternately at each end.

The large stuff must be used to form the exterior, and the smaller twigs the interior of the fascine.

Before binding the fascine it must be compressed with a fascine choaker, which consists of a cord or chain equal in length to 1½ times the circumference of the fascine, fastened at one end to a lever 5 feet long and 2½ inches in diameter, with a loop at the other end, into which, after passing the chain round the fascine near the part to be bound, a lever, similar to the one already described, is inserted, and the brushwood is squeezed tightly together until the gad is tied. The fascine must be compressed in a similar man-

her before each gad is fastened, and be measured with a cord to ascertain that it is of the required size, unless a mark be placed on the chain of the choaker to shew when it is of a proper thickness. The weight of a fascine of this kind is about 33 lbs.*

Three men can make a 6 feet fascine in 20 minutes. Two of the workmen place the brushwood, while the third prepares the gads, which is the only difficult part of the operation, and therefore requires previous instructions.

75. If large brushwood can be procured, the fascines should be made 18 feet long, the strength of the revetment being materially increased by diminishing the number of joints, and using fascines of greater diameter. When the fascines are 18 feet long, they are made 9 inches in diameter, and the gads are placed at 18 inches apart.

The fascine horses for these large fascines should be placed one yard apart, in a right line, and on the same level, otherwise the fascine would be crooked, and troublesome to work with. A fascine of the above description weighs about 2 cwt.

Four men can make an 18 feet fascine in two hours, or if the wood be cut and brought to them, they can make four fascines in the same time.

They require three bill-hooks, one saw, one fascine-choaker (each lever about 6 feet long,) and six fascine horses. Three men prepare the brush-

* This weight must evidently be very variable, depending on the description of wood used, and its degree of humidity.

wood, and lay it on the horses, while the fourth makes the gads.

When three or four thread-spun yarn can be procured to tie the fascines, it will save much time and labour.

76. The revetment is formed in proportion as the parapet is raised, the first fascine being one-half buried in the banquette, with three pickets driven vertically through it, each picket from 3 to 4 feet long, and from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter at the thickest end. The second row of fascines is then laid a little in front of the first, so as to form the required slope, and three pickets are driven through each fascine, the extreme ones through the fascine previously laid in the direction of the slope, the other perpendicular to the slope. The Austrians, instead of the middle picket, use an anchoring picket driven into the middle of the mass of the parapet, and a long withe or cord being passed round the centre of the fascine, is secured to the end of the picket, as in Fig. 38, &c.: great stability is thus given to the revetment of the interior slope. The joints of the different rows of fascines should be so broken that no two adjoining ones may be in the same line, and the ends of the fascines at the angles should alternately be flush with, and be inserted in, the parapet; care being taken to lay the fascines so that the ties of the gads may be concealed in the parapets.

Six rows of large fascines are sufficient to form the revetment of a parapet, the upper row being covered with a layer of sods, the grass upwards.

When fascines of 7 inches in diameter are used, eight rows are required.

Hurdle Revetment.

77. The hurdle revetment is made by driving strong pickets 18 inches or 2 feet into the earth, and from 8 to 10 inches apart, in the direction of the slope: flexible branches or rods are then entwined with the pickets, all the ends being inserted in the parapet.

The upper layer of rods is secured with gads to the pickets, to prevent the work getting undone.

To counteract the thrust of the parapet, each picket should be secured with two or three anchoring pickets, as represented in Fig. 53.

This kind of revetment is easily and speedily formed; and if proper care be taken in its construction, it will be found to be a very good one.

Sod Revetments.

78. The third kind of revetment is made with sods of unequal sizes, called headers and stretchers. The headers are 1 foot 6 inches long, 1 foot wide, and 4½ inches thick, if the soil will allow of their being cut to that depth.

The stretchers are 1 foot wide and long, and 4½ inches thick. Sometimes the sods are cut all of the same dimensions, viz. 1½ feet long and 1 foot wide; the sod is then cut diagonally across so as to form two, and they are then all laid headers. This saves nearly half the turf and

labour. The sods should be cut from meadows well provided with grass, previously mown, and, if possible, watered, that the earth may more firmly adhere to the roots of the grass; but the sods should not be laid or built when wet, because they would shrink in dry weather, and all the joints would open; if, when laid, they are moderately dry, the revetment will always keep solid.

The sod-work is laid with the grass downwards, either alternately headers and stretchers, or two stretchers to one header; care being taken that the joints of no two rows fall immediately over one another: this is termed *breaking joint*. If the layers of sods are laid perpendicular to the slope, they will resist the thrust of the parapet better than if laid horizontally. Each sod should have two or three pegs driven through it to secure it to the work beneath. The sod-work should be carried up at the same time the parapet is formed, and the earth near it be well rammed. If layers of small brushwood can be procured to mix with the earth of the parapet, as represented in Fig. 25, it will contribute to the stability of the work.

When the revetment is completed, the whole should be cut off smooth to the proper slope; a pair of hedge-clippers, or a cutting-knife, will answer well for this purpose.

Revetments of sod-work are capable of being made with great perfection, and when so made, are very durable: they are therefore commonly used where nicety of appearance is required. One man can lay 19 square yards of sod-work in a day

of eight hours, when the sods are brought to the spot, and require no previous trimming.

79. To cut the sods from the meadows, first trace with a spade or pick-axe lines to mark the dimensions of the sods, or, to trace these lines, a small description of plough, drawn by five or six men, might be used. As soon as the compartments are marked, the sods are cut with a sharp-pointed spade made for the purpose, or they may be traced and cut with a common spade.

Revetments of Planks, &c.

80. When neither fascines nor sods can be procured, as will often be the case in besieged towns, the floors of the houses will always afford an abundant supply of materials for forming the revetments of the interior intrenchments, which in their details of execution are similar to field-works.

If plank or timber cannot be procured, a good revetment may be made by mixing the most binding earth you can find with chopped straw or rushes; this being wetted and well rammed, will form a very solid and durable revetment. The parapet should never be revetted with masonry, except in situations where artillery cannot be brought to attack the work. Casks may often be used with advantage to revet the interior of works.

Revetment of Gabions.

81. Gabions are cylindrical baskets open at both ends, and are very commonly used to revet

parapets: they are made of various dimensions; for the interior of parapets they should be 3 feet in height and diameter. The common gabions, viz. those used by sappers, are two feet in diameter, and 2 feet 9 inches high. To make them, a directing circle, consisting of two hoops kept apart by bits of wood, to which both hoops are secured with pack-thread, is first made. The diameter of the hoops must be such as to permit of the pickets for the gabion being driven between the exterior of the one and the interior of the other, as shewn in Fig. 147. The directing circle is then laid on a level piece of ground, and seven, eight, or nine pickets are driven at equal distances apart, between the hoops, the number of pickets depending on the size of the rods or brushwood with which the basket-work is to be made. The circle is then raised, and fastened to the middle of the pickets, and the web is made above it, two or three rods being used at the same time, the workman twisting them round each other while he interlaces them with the pickets; striking down the web from time to time with a stick, in order to give the basket-work as much solidity as possible. The *randing* or basket-work is continued to near the top of the pickets, where it is secured with four *gads*, each one passed round one of the pickets, and four or five of the rods; which should be from 8 to 10 feet long, and not more than half an inch in diameter. The gabion is then pulled up, the finished end is placed on the ground, and the directing circle being removed, the remainder of the web is finished and

secured as before described. In the above manner two men can make a gabion in ¾ of an hour, using about 80 rods for each gabion.

In forming the revetment the gabions are placed touching each other with a slope of ¼; the first row is surmounted with two rows of fascines side by side, and a second row of gabions rests on them.

If the parapet have a banquette, a row of fascines should be laid—one half of each fascine below the level of the banquette; a row of gabions resting on these fascines, with a row of fascines above them, completes the revetment.

Revetment of Sand-bags.

82. This description of revetment is the most expeditiously formed, but being also the most perishable, is only used in cases where cover is required to be speedily obtained: as, for instance, when troops are disembarked on an enemy's coast, where fascines and gabions cannot be procured.

The sand-bags should not be more than three-fourths filled, and the top be loosely tied; they are laid alternately headers and stretchers, care being taken to break the joints, and to ram the earth of the parapet well, flattening each layer of sand-bags with a smart stroke of a shovel.

Sand-bags are usually made of coarse canvass, and are put up in packages containing 200. When empty, they are 2 feet 8 inches long, and 1 foot 2 inches wide; when filled, they are 2 feet 3 inches

long and 9 inches in diameter. To calculate the number required to revet a given surface, allow 24 sand-bags to 10 superficial feet of revetment.

Escarp Revetments.

83. When the earth will not stand at a slope of $\frac{1}{3}$, as is very generally the case, the escarps of important works should, if possible, be revetted, or otherwise protected. Trunks of trees form the best description of protection for escarps. They should be planted vertically, and touching each other, their ends sunk 3 or 4 feet into the earth. When the escarp is covered in this manner, it should be given the natural slope of the earth; and the trunks of trees may be placed either at the foot, or 4 feet in front of it, when a line of musketry fire is required from behind the escarp revetment. In this case, loop-holes are pierced in the timber 3 feet apart, and it is called a *stoccade*. The ditch must be made deeper in front than in rear of the stoccade, to prevent the enemy closing on the loop-holes; and ready means of communication between the interior of the work and the ditch should be provided.

84. A plank revetment, sustained with triangular frames, arranged as in Fig. 33, is sometimes used, when time for its formation can be allowed. This revetment may be made more simple by constructing it as in Fig. 34.

It must be admitted as a disadvantage of the revetment Fig. 33, that the parapet cannot be formed until the revetment is completed, on

account of the excavations required for the introduction of the frames.

85. In well-wooded countries, a stoccade constructed of round timbers, about 1 foot in diameter, and from 10 to 13 feet high, may often be advantageously used to supply the place of earthen works. Fig. 35 is the elevation of a stoccade as above described. If there be no ditch in front, a banquette must be thrown up in the interior, and the loop-holes be pierced at a sufficient height to prevent the enemy making use of them.

SECTION III.

OF BARBETTES, TRAVERSES, ETC.

Of Barbettes and Traverses.

86. When field-works are armed with artillery, the guns may be either so placed as to fire over the parapet, or openings may be formed in it called *embrasures*, for the guns to fire through. The first arrangement is adopted when the fire of the guns is required to be distributed over the whole of the space in front of the battery—the last when required for definite objects only.

When the platform for the guns is so raised that they can fire over the parapet, the battery thus formed is called a *barbette*. There are two descriptions of barbette batteries: the first, when the guns are mounted on platforms so constructed

that they may be fired over a parapet of the ordinary height; the second, when a part of the interior of a work is filled up to a sufficient height, to permit of a gun on a travelling carriage, when mounted on the barbette, being fired over the parapet.

In the latter case, the *terreplein* of the barbette should be $3\frac{1}{2}$ feet below the crest of the parapet.

A field-piece requires a space of about 15 feet in width and 20 in length; so that the superior surface or terreplein of a barbette for one piece only, would be a rectangle of 15 feet, by 20 or 24 feet, the longest side perpendicular to the parapet.

87. Ramps are formed to ascend the barbettes, and for the height commonly required they are given a slope of $\frac{1}{6}$, *i. e.* for each foot in height the ramp should have 6 feet of base. If the height of the ramp be more than 9 feet, the slope must be made less than $\frac{1}{6}$, because it should be proportioned to the duration of the effort required to ascend it. From 9 to 18 feet in height, the slope should therefore be at $\frac{1}{8}$; from 18 to 27 feet, at $\frac{1}{10}$; and from 27 to 36 feet, at $\frac{1}{15}$.

Ramps in field-works are made from 8 to 10 feet wide, that there may be sufficient room to drag a field-piece up them.

Sometimes two ramps are formed to one barbette, which facilitates the circulation. In this case, they should be placed parallel to the faces of the work, as represented in Fig. 36, which is the plan of a barbette battery for three guns, placed at the salient angle of a work.

Between the guns there are free spaces, the size of which varies in proportion to the opening of the salient angle: these spaces are useful to pile the shot in.

We have supposed, in Fig. 36, that a gun requires 18 feet of parapet, in order to obtain room for placing ourselves under cover, which may be done in the following manner:—

88. To destroy in part the effect of the converging fire, which would be directed against the pieces *en barbette*, if occupying a salient angle, a *bonnette* of 2 or 3 feet in height is raised on the parapet between the guns. This bonnette, though it partly protects the guns from enfilade fire, has the defect of limiting their lateral range, and cannot always therefore be conveniently used. The interior and exterior slopes of the bonnette are continuations of those of the parapet, and a slight superior slope is given to it, to carry off the water. The best method of covering the guns is to throw up a traverse on their exposed flank.

That the traverse may occupy as small a space as possible, its sides must be revetted with fascines, plank, or gabions. When made with gabions of a common size, three or four rows are placed touching each other; they are then filled with earth, a layer of fascines is laid on the top of them, and then another tier of gabions, consisting of one row less than in the bottom; a slope towards the interior of the traverse being given to the exterior gabions.

Gabions for traverses are sometimes made

from $7\frac{1}{2}$ to 8 feet high, and from 4 to $4\frac{1}{2}$ feet in diameter. Two rows of these gabions make a good traverse.

If the barbette battery cannot be taken in flank by the enemy's artillery, the gunners may be sufficiently covered by placing a single row of gabions on the parapet between the guns, with two sand-bags placed on end, one above the other, between each pair of gabions, to prevent the shot passing between them.

Another kind of traverse, which has already been noticed, is placed to cover the entrance of a work. As these traverses are intended to resist the projectiles of the enemy equally with the other parapets, the same profile must be given to them, except that their exterior slopes and ends should, when practicable, be revetted, in order that they may not occupy too large a portion of the interior space.

89. Traverses still more important may sometimes be required in order to cover the interior of a work from the view of the neighbouring heights. The particular method of determining the position and height of these traverses will be treated of in the chapter on "Defilement;" at present remarking only, that passages should be formed in them to communicate between the different parts of the work, and that powder-magazines may often be constructed in them with great advantage.

Of Passages.

90. Passages through a traverse may be made with great gallery frames and sheeting, art. 207, or with fascines only. Figs. 37 and 38 shew the manner of forming these passages.

The fascines for the top should be stronger than common fascines; they are made 12 feet long and 11 inches in diameter.

The passages should be $6\frac{1}{2}$ feet high in the clear, and $6\frac{1}{2}$ feet wide at the bottom, to admit of the passage of artillery.

When formed with gallery frames, the frames should be placed 3 feet apart from centre to centre. The passages must be made at the same time that the traverse is thrown up, and if a great mass of earth be required above the ceiling, they must not be covered with fascines. Then strong timber should be laid across the top, viz. of 9 or 10 inches square, or rafters, flooring joists, or planks on edge with short bearings, covered with boards or fascines. The passages forming the entrances to works are generally uncovered, and cut through the parapet in the least exposed parts: that they may be of as little detriment as possible to the defence, their sides should be revetted at a steep slope, the bottom being made only of sufficient width to permit the passage of artillery, viz. $6\frac{1}{2}$ or 7 feet.

These passages are usually closed either with a barrier, or *chevaux-de-frise*, the manner of constructing which is explained under the head of "Barriers," art. 97, *et seq.*

Bridges of Communication.

91. To communicate with the interior of a work, a bridge must be formed across the ditch. This bridge will generally consist of two parts, one standing or permanent, the other moveable.

If the ditch be not more than 12 feet wide, the whole bridge may be made moveable. Four or five sleepers laid across the ditch, of not less than 6 by 4 inches, are covered with plank; a piece of smaller scantling is laid on the top of the plank immediately above the exterior sleepers, to which it is secured with *rack-lashings*, notches being cut in the ends of two adjoining planks for their introduction. The rack-lashing consists of a piece of stout rope fastened to the thick end of a pointed stick, the rope is passed round the pieces of timber to be secured, then twice round itself, as in Fig. 39, the end of the stick is then put into the loose *gromet* so formed, and twisted round until the whole is firmly secured, when the stick is turned flat on the upper piece of scantling.

When the ditch is more than 12 feet wide, a trestle or frame, as represented in Fig. 40, must be placed in the middle to support the sleepers. The height of the frame will depend on the depth of the ditch. The transom, or upper piece, should be 10 feet long, and the legs be wider apart below than above, in order to give steadiness to the bridge.

When a bridge is more than 24 feet long, two or more frames must be placed in the ditch to support it. These frames should not be more than

12 feet apart. The sleepers should be from 7 to 8 inches square, and all except the last bay of the bridge may be permanently fastened; a piece of scantling being nailed over the planking on each side of the bridge, to prevent the wheels of carriages, &c. going too near the sides.

92. When rough timber only can be procured, and no plank, a bridge may be formed much in the same manner as already described: stout straight limbs must be selected for the sleepers, which should have but short bearings; they may then be covered with strong hurdles, over which a layer of sods, and then a small quantity of gravel, may be laid.

Of Powder-Magazines.

93. Magazines are usually constructed either in the interior of traverses, or by the side of them.

Sometimes casemates of timber are formed in the interior of large traverses to serve as barracks; but this would only be done in works of importance. These magazines and barracks may be formed in the same manner as the passages, with frames and sheeting.

94. The best description of field powder-magazine, is constructed of splinter-proof timbers of about 10 inches by 8, placed against a substantial and well revetted traverse at an angle of from 45° to 50°, Fig. 41, and strengthened externally with 2 feet of sod-work, or earth in sand-bags, the whole covered with tarpaulins; or the tarpaulin may be placed next to the splinter-proof timbers,

or with an intervening row of sand-bags only; it is not then exposed to external injury; but if accidentally damaged, it cannot be readily repaired. If the site of the work be favourable to drainage, the floor of the magazine may be sunk 2, 3, or even 4 feet below the surface of the earth.

A passage to the magazine may be made with common gallery frames and sheeting, or in the same manner as covered passages, Fig. 38.

Magazines are sometimes made, as in Fig. 42, with a double row of splinter-proof timbers meeting in a ridge; the bottom frame of the magazine should then be strongly connected at both ends, and at intervals of about 6 feet, by stout timbers framed into, or halved and bolted, to the long sides of the rectangle, as in Fig. 43; the ends of the splinter-proof timbers are then notched to fit into the bottom frame or sill.

94. When timber cannot be procured for making magazines, casks or barrels may be buried in the traverse, reverse of the barbette, or parapet, to contain a small stock of ammunition.

Of Embrasures.

95. Embrasures are seldom formed in the parapets of field-works unless the guns are required to fire only in a particular direction, as before explained in art. 86, such as to flank a scarped slope, ditch, abatis, or wall, &c.

In general, the parapet is in the first instance thrown up, and the embrasures are afterwards cut out of it where required. In order that the men

who serve the guns may be little exposed, the interior of the embrasure should not be more than 20 inches wide, its *cheeks* or sides being built up with as little slope as possible.

The opening of the embrasure measured on its *sill* or *sole*,* under the exterior crest, is made equal to half the thickness of the parapet. That part of the interior slope of the parapet immediately beneath the embrasure is called the *genouillère;* its height for field-guns should be 3½ feet. If the cheeks of an embrasure were of any great height, the explosions of the gun would soon occasion their fall; and thus render the embrasure unserviceable. For the above reason, the sill of an embrasure should, in ordinary cases, not be more than 4 feet below the crest of the parapet; if, therefore, the parapet were more than 8 feet high, it would be necessary to raise the terreplein or platform for the gun. The portion of parapet contained between any two embrasures is called a *merlon.*

The best revetment for the cheeks of an em-embrasure is formed with plank and timber, as in Figs. 33 and 34, the only difference in the arrangement being, that the plank should be spiked to the front of the upright timbers, so as to present a smooth surface for the cheek of the embrasure, instead of being introduced behind the timbers, as in those figures. Large fascines are, however, more generally used for revetting embrasures.

* From *Fr.* "seuil," a threshold.

The ends of the fascines are laid flush with the interior slope of the parapet, and the interior opening of the embrasures is carried up perpendicularly.

Under the exterior crest each fascine is made to cover not much more than half of the one next beneath it, being turned towards the interior of the merlon, so that the cheeks of this part form an angle of about 54° with the horizon. The embrasures in siege batteries are generally revetted with gabions; and in order to protect them from the effects of rapid firing, each gabion is rolled or sewn up in a strip of raw hide.

To trace an oblique embrasure, set off on the directing line C H, Fig. 44, C D equal to the thickness of the parapet; at D draw a perpendicular across C D, and make D E, D F, each equal to $\frac{1}{4}$ of C D: this determines the width of the embrasure at that point; in other respects it is finished as already described.

In Fig. 44 two embrasures are shewn, and also the plan of an embrasure for a howitzer marked A: the sill of this embrasure is given a slope from the exterior crest towards the interior of the work, and its opening is made $4\frac{1}{2}$ or 5 feet wide, on the interior crest.

Of Platforms.

96. To facilitate the working of a gun it must be placed on a platform of timber and plank, or when required to fire only in one direction, timbers to take the wheels and trail will suffice.

If the gun fire through an embrasure, an inclination of 6 inches is given to the platform from the rear to the front. Platforms on barbettes, or for mortars, should be perfectly level.

When a gun is required only to fire in one direction, the platform should be rectangular, 10 feet by 17 feet for heavy artillery, and 9 by 15 for field-guns.

Mortar platforms should be 8 feet square. The dimensions for the platforms of barbettes must depend on the extent of lateral range which may be required.

In laying a gun-platform the first thing to be done is to fix the *hurter*, which may be a piece of timber 7 or 8 feet long, and 7 inches square, or a strong fascine may be used. The hurter is intended to take the wheels or trucks of the carriage when the gun is run out, and to prevent their damaging the interior slope of the parapet. The position of the hurter necessarily depends, therefore, on the steepness of the interior slope.

The hurter should be placed perpendicular to the axis or central line of the embrasure.

Three, four, or five sleepers, of from 6 to 8 inches square, are then laid, their upper surface on a level with the bottom of the hurter, and they are covered with 2-inch plank, nailed down when three sleepers are used; but if there be four or five sleepers, the platform may be racked down in the manner described in art. 91.

Of Barriers.

97. The entrances to enclosed works are generally secured either with a barrier gate or *chevaux-de-frise.*

When the passage into a work is only 6½ feet wide, a single gate will be sufficient to close it. This gate should not be less than 6½ feet high. It is usually composed of two upright *stiles* and two horizontal *rails** framed together, and strengthened with a diagonal brace, represented in Fig. 45; six or eight palisades of about 4 inches square are halved into these pieces, and spiked at all the halvings. Stout hinges are nailed or fastened with screw-bolts to the rails.

The gate turns between two posts of about 1 foot square, their ends sunk 3 feet into the earth, and connected 1 foot beneath the level of the ground by a sill of similar dimensions. The gate is hung to one of the posts, and a slip of wood is nailed to the other to take the barrier when closed.

The gate should open internally, and be fastened with a bar of wood or iron extending from post to post.

98. If it were required to close a much-frequented road, the communication by which you wished to preserve, as is always the case when the environs of a town or village are intrenched, the barrier gates should be 10 feet wide in the clear;

* The rails are frequently cut out of scantling 7 by 7 inches. The section of the rail is then a trapezoid, and its parallel sides are 5 and 2 inches long.

they will then consist of two parts similar in construction to the barrier already described. In the centre of the sill a piece of iron or hard wood must be fastened to take the ends of the bottom of the barrier; and to prevent the wheels of carriages damaging the gate-posts, as well as to strengthen them, two braces may be framed into the angles of the sill and posts.

Of Chevaux-de-Frise.

99. The chevaux-de-frise, when intended as a barrier, is made of a piece of wood equal in length to the width of the passage, and about 1 foot square, or in diameter, traversed with several pointed poles or spears $6\frac{1}{2}$ feet long, Fig. 46. The spears are commonly placed so as to present two rows of points to the enemy, and they should be of sufficient strength to prevent a man breaking them. One end of the chevaux-de-frise turns on a pivot, and the other is supported by a wheel, which facilitates its movement: this end is brought against a stout post, to which it is secured with a chain. When the spears of the chevaux-de-frise are so arranged as to present three rows of points to the enemy, Fig. 46, the horizontal spear renders it more difficult to break the barrier.

Having given a general description of the details for the construction of intrenchments, we will proceed to treat of the means of adding to their ordinary strength, and thus rendering them capable of opposing a greater degree of resistance.

CHAPTER IV.

SECTION I.

OF OBSTACLES.

100. The ditches of field-works are in general but a slight impediment to the enemy's progress; for if they were not more than 6½ or 8 feet deep, as is often the case, it would be very easy to leap into them, though encumbered with the weight of the knapsack and musket. Unless the work be traced with flank defence, the enemy, when in the ditch, is no longer exposed to the musketry fire of the parapets: it is therefore desirable to place as many obstacles as possible to his progress, in front of the counterscarp; and at the same time it should always be remembered, that the nearer those obstacles are to the counterscarp, the better they will fulfil their object.

Of Abatis.

101. One of the best obstacles which can be formed is an abatis, consisting of stout limbs of trees, well intermingled, stripped of leaves and small branches; the large ones being pointed, and turned towards the enemy, presenting to them a great number of points, as in Fig. 47.

These limbs or branches have their thick ends buried in the earth, or secured to strong stakes

driven into the ground; and they may be covered from the view of the enemy by an advanced glacis, the slope of which should be directed to the crest of the parapet in the rear. The earth required to form the advanced glacis is taken from the rear, by producing the slope of the inner glacis; and in this excavation the abatis is placed.

When placed in the manner above described, it does not mask the fire of the work, and cannot be easily destroyed by the enemy.

There is no reason why the advanced glacis may not be of the same height as the inner one, but it is almost always made lower. It would be useless attempting to fix dimensions for works of this description, which vary with every different situation. All that is necessary to observe, is, that the slopes of the glacis should be seen by the work—the crests be at least 5½ feet below that of the parapet—and the abatis be covered from the direct fire of the enemy.

Hard and tough woods are the best for an abatis: pine is the worst, for it is easily broken, and burns readily when fresh cut, which is not the case with hard woods. The abatis should not be felled long before it is wanted.

This is of all obstacles the most military, and the easiest of execution. It is but imperfectly replaced by *chevaux-de-frise*,* which are difficult to make, and should therefore be rejected as an obstacle, except on a very small scale.

* The best *chevaux-de-frise* ever used were made of sword-blades.

Of Military Pits.

102. Military pits* are excavations, formed either in the shape of an inverted cone or square pyramid.

They are usually placed in two or three rows, as in Fig. 48, round about the counterscarp, and principally opposite the salient angles.

In the centre of each pit, a pointed palisade, or stake is fixed, the point on a level with the ground.

These pits are principally used in situations where cavalry could approach.

They should be made 7 or 8 feet deep, that the enemy may not see to fire out of them. If made only 2 or $2\frac{1}{2}$ feet deep, and well staked at bottom and in the intervening spaces, they will be a good obstacle. The earth excavated for the pits may be formed into a glacis to conceal them, or to cover an abatis in front. In this case, the small branches cut from the abatis may be laid over the pits, that the enemy may not be able to distinguish, and by leaping avoid them.

Of Inundations.

103. When field-works are constructed near a rivulet, the waters should be retained by dams, that they may accumulate in front of the intrenchment, and thus form an inundation.

If the ditches of a work can be filled with

* *Fr.* Trous de loup.

water, it is an excellent means of defence, and must not be neglected, since it completely remedies the defect of dead angles, and prevents the work being carried by assault. This remedy has, however, its inconveniences: in winter, the waters may freeze, and then the ditch would be altogether useless. The only means of obviating this disadvantage, is to break the ice every morning and evening, and throw water on the parapets, which, when frozen, would render them so slippery that it would be difficult to get over them.

When the inundation is shallow, ditches should be cut chequer-wise through it, of about 12 feet long, 6 feet wide, and of sufficient depth to prevent men wading through them, when the waters of the inundation are extended. These cuts will render the access insecure and difficult. The earth excavated should be spread abroad, so as not to form islets, which might facilitate the passage.

104. If the intrenchments are traversed by a rivulet perpendicular to their general outline, and the waters can be retained by forming a dam of the glacis or parapet of the intrenchment, the inundation will offer a great obstacle to the flank movements of the enemy; and if you have established a ready communication in the rear of your intrenchments, it will enable you, when his attack is decided, to withdraw your troops from that part which he cannot approach, and to meet him on either side of the inundation with the whole of your forces.

105. An inundation parallel to an intrench-

ment is not, in general, so advantageous as one perpendicular to it; the former having the disadvantage of being as great an obstacle to your attack as to that of the enemy. It may indeed compel him to direct his attack on some other portion of your intrenchments, and thus reduce the assailable extent of the position.

The dams of a parallel inundation are in most situations more easily assailed than those of an inundation perpendicular to the intrenchment, because, in the first case, the dam is perpendicular to the intrenchment, consequently one end is at a greater distance from your works than the other, and the necessity of having those points well defended will often lead to so extensive an arrangement of works as could not be with propriety undertaken in the field; while the dam in the latter case may be within your line of works, and form one of your communications across the stream.

Of Pickets.

106. The small branches cut from an abatis may be rendered useful by making pickets of them; and after driving them into the ground on the glacis, or between the military pits, cutting the ends exposed to a point, allowing them to project about one or two feet above the ground, as in Fig. 47.

If the ground on which the intrenchment is thrown up be covered with vines or low bushes, the vines should be left intact. The stems of some

of the bushes should be cut into pointed pickets, and of others only half way through; the boughs of the brushwood lying across, and interlacing with one another, will thus form a very good obstacle, called *an entanglement*.

On the glacis, harrows may be buried with the spikes exposed; or broken wheels, and large rough paving stones, be strewed about to break the order of a night attack. In warm climates, there are many plants of rapid growth which form powerful natural obstacles; such, for instance, as the aloe. A good aloe, or prickly-pear hedge, is one of the most impenetrable natural obstacles that could be presented to an enemy.

Of Crows' Feet.

107. Crows' feet are formed of three or more short stout nails, connected together at their larger ends, so that in whatever position they may be placed, they will always have one point upwards. They are principally used as an impediment against cavalry.

Of Palisades and Fraises.

108. Palisades are made of large branches of trees, or young trees split or sawn in two or more pieces, according to their size. They are of a triangular form, each side of the triangle being 7 or 8 inches long. The palisade should be about 10 feet long. To plant it, a narrow trench is dug, from 3 to 4 feet deep, in which the palisades are placed upright, 4 inches apart. The earth is then

filled into the trench, and well rammed to secure them below; and they are nailed to a band or riband 4 inches by 2½ inches, either within 1 foot of the top of the palisade, or near the bottom of it. The riband must be placed on the inside of the palisade. It would be an advantage to have them also nailed to a riband, concealed in the ground, that the enemy might not be able to pull them up singly.

If the palisade be required to remain long in the ground, the ends should be charred or partly burnt; it will then be less injured by the moisture of the earth.

Oak palisades are the best. The upper part of each palisade is terminated in a point, to which an iron spike is often attached. The best position for a palisade is at the foot of the counterscarp, Fig. 50; it is then sheltered from the direct fire of the enemy; but it may be received as a maxim, that a palisade is not of much use if exposed to the enemy's artillery, or unless, while destroying it, he is exposed to the fire of the work. Trunks of young trees 14 or 15 feet long have been used as a palisade with great effect. If more than 1 foot in diameter, they may be sawn down the middle to form two palisades.

109. Fraises are palisades placed horizontally, or but slightly inclined to the horizon. They are recommended by most authors to be placed along the crest of the escarp, in which case the work should have a glacis to cover the fraise from direct fire.

The stakes of the fraise should be 11 feet long, that they may be buried $4\frac{1}{2}$ feet in the parapet, rest $1\frac{1}{2}$ feet on the berm, and project 5 feet beyond the escarp. They are spiked to a riband laid on the berm, and on their upper end another riband is spiked, which being afterwards covered with the earth of the parapet, renders them firm and not easily to be displaced. The points should not be less than 7 feet above the level of the ditch.

110. The fraise might be more advantageously placed 2 or 3 feet below the crest of the counterscarp; there it would be concealed from view, and not be liable to be damaged by direct fire; the enemy would also be exposed to the musketry fire of the parapet while destroying it. In this case the fraise should be made of such strength as to prevent an enemy breaking it down by his weight, while, to increase the difficulty of leaping into the ditch from the end of the fraise, the escarp may be carried down to a point, as in Fig. 49; which is always done in works of slight profile.

111. When a palisade is planted at the foot of the counterscarp, the ditch may be deepened in rear, as in Fig. 50. This arrangement is advantageous when the ground will stand at a good slope, for the height of the escarp is thus much increased with little labour; it also prevents the enemy accumulating in the ditch; and consequently the slopes of the escarp and counterscarp should always be carried down to a point, if the ditches have no flank defence.

SECTION II.

DEFENCE OF THE DITCH.

112. In the detached works constructed in the field, the ditches rarely receive any flank defence. The enemy, when there, is exposed only to the vertical fire of the work, viz. the hand-grenades and shells thrown by the defenders.

This defect is so material, that in important works no opportunity of procuring flank defence for the ditches, however small in quantity, should be neglected.

Of Stoccades.

113. If the work were a lunette, a stoccade or strong palisade may be placed across the ditch at the angles of the shoulder, with loop-holes cut in the stoccade for the men to fire through. A means of getting into the ditch of the flank must be provided, and the work itself be so situated that it cannot be assailed by the gorge, to make this defence of any service.

Of Caponnières.

114. For quadrilateral redoubts a double stoccade is formed at two opposite angles, so as to give a flank fire in all the ditches. The stoccade is covered with planks and earth, is made 6 feet wide, and 6½ feet high in the clear, and is called a *caponnière.*

A gallery is driven to communicate between the interior of the work and the caponnière, or an

entrance may be formed at the end next to the escarp, closed by a barrier 3 feet wide. The caponnière must not touch the counterscarp, otherwise it would serve as a bridge for the enemy; the end of it may, therefore, be terminated in a slope, or the width of the ditch must be increased opposite the end of the caponnière, and small ditches be cut in the main ditch parallel to its faces, to prevent the enemy closing on the loop-holes. These small ditches may be protected by a palisade; and, as an additional defence, a flanking fire may be obtained near the escarp through a loop-holed stoccade. Fig. 51 is the plan of a caponnière, combining all the details above mentioned. In Fig. 52 the section of a caponnière is given, with loop-holes pierced near the bottom of the ditch; and this is in some respects a better arrangement than the one before described, this caponnière being less exposed to suffer from the fire of the enemy's artillery, and less likely to assist him in escalading the work.

115. The small width of common ditches, the great quantity of wood, and the time required to construct caponnières, occasion their being seldom used; it is a means of defence which can only be resorted to when abundance of time is allowed, and supplies of wood are near at hand, or easily obtained.

Of Counterscarp Galleries.

116. Loop-holed galleries are sometimes constructed of timber under the counterscarp of the

salient angles of works, to see the ditches in reverse, Fig. 53. The entrance to the gallery should be closed by a strong door, and a sufficient force to defend it should be at all times shut up in it, when an attack is possible.

117. Besides the means already pointed out for the defence of the ditch, every kind of obstacle should be there accumulated, and a supply of large stones be collected in the interior of a work to roll down on the enemy.

SECTION III.

INTERIOR INTRENCHMENTS.

118. The most certain mode of giving confidence to the defenders, and consequently increasing the strength of a work, is to secure to them the means of retreat; to offer them a last place of refuge, in which they may obtain terms of capitulation, honourable in proportion to the courage displayed in their previous defence.

These interior intrenchments are only applicable to works of great magnitude, and should be constructed of such a form that no point of the principal work may be concealed from their view, and on which their fire cannot be directed. Their capacity must be proportioned to the number of men they are intended to contain, without, at the same time, obstructing the defence of the main

work; a condition in many cases not easily to be observed. They are commonly made with stout timbers placed vertically, touching one another, and pierced with loop-holes; they should be covered with stout beams placed at a distance apart equal to their smallest dimension, on which two rows of fascines being laid, the whole should then be covered with 3 or 4 feet of earth. A defensive barrack of the above description is also called a block-house. To expose the least possible quantity of the wood-work, the block-house should have a ditch of about 6 feet wide, and deep, dug round it, and the earth excavated should be heaped against it, up to the bottom of the loop-holes.

The defensive barrack above described should be 7 feet high in the clear, and 20 feet wide; this width will allow of there being two rows of guard-beds, with room to circulate between them. The beds serve as a banquette to the loop-holes.

The length of the barrack must depend on the size of the work in which it is constructed. In the interior, a magazine should be made; and provisions may be stored on planks suspended from the ceiling immediately above the foot of the beds. The internal arrangements must, however, depend on the form and nature of the ground, which in one case dictates modes of construction that in another would be useless. It is, therefore, impossible to assign in an invariable manner the form and dimensions of every class of works required in the field: all that can be done is to lay models to be imitated so far as the nature

of the case will permit, but which should on no account be servilely copied.

119. In very extensive works an interior redoubt may be made of earth, in which case a small command over the parapet of the principal intrenchment must be given to that of the interior work; not, as might be imagined, to procure a double row of fire, but that the enemy may not, when on the parapet of the principal intrenchment, be able to discover the interior of the inner work; strictly speaking, it would be necessary to give a command of 6 feet to the latter work, which would then not only have a relief of 14 feet above the level of the ground, and therefore pass the limit laid down in art. 62, but would also with difficulty see the edge of its counterscarp, and the interior of the principal work; its command should, therefore, in ordinary cases, not exceed 4 feet. In these elevated works, the slopes of the banquette should be converted into steps, that the interior space may be as capacious as possible.

An additional cover may, if required, be easily obtained by placing two rows of sand-bags on the parapet, leaving intervals in the lower row to serve as loop-holes.

Of Tambours.

120. It often happens that the interior defence consists only of a stoccade or simple palisade, a banquette being formed with the earth excavated from a small ditch in front, so that the defenders

may be placed above the assailants, and that the latter may thus be prevented making use of the loop-holes.

These small redoubts or tambours, though weak in themselves, are of use when nothing better can be done. In the event of a work being surprised, they may enable the garrison to recover from their first panic.

The timber for tambours to resist musketry fire, should be from 6 to 8 inches square; to resist field-artillery, two rows of timber, each 12 inches square, are required; the second row rising only to the level of the bottom of the loop-holes.

121. Loop-holes are generally made wide and low on the inside, narrow and high externally. The common dimensions are, in walls of from 2 to $2\frac{1}{2}$ feet thick,

Interior width	15 inches.
Exterior do.	4
Interior height	9
Exterior do.	20

In timber of from 6 to 8 inches thick,

Interior width	8 inches.
Exterior do.	$2\frac{1}{2}$
Height	12

CHAPTER V.

SECTION I.

ON THE MANNER OF OCCUPYING IRREGULAR SITES.

122. As yet we have not supposed the works to be situated on, or to be surrounded by, high grounds; on the contrary, they have been imagined to be constructed on level ground, without any irregularities within the range of artillery.

Such sites are, however, very rarely found; works are in most cases constructed on elevated spots, and often so near to other heights, that if the enemy were in possession of the latter, he could, from them, see over the parapets, if only 8 feet high. This defect can only be remedied by increasing the relief, constructing traverses to cover the interior from the view of an enemy, or excavating the terrepleins.

To follow the irregularity of the ground in the tracing of a work, so as not to require too great a relief, obtaining at the same time cover from the view of the neighbouring heights; and to expose the works as little as possible to the enemy's fire, without compromising the immediate object of the work, are the most delicate operations required of the field engineer.

123. The heights on which the intrenchments are thrown up, and those by which they are sur-

rounded, both contribute to modify the form and relief of the works. We shall first treat of the influence of the former, and then point out the means of avoiding the dangerous effects of the latter.

1st. The slopes of the heights on which field-works are to be constructed, may be so steep as to be nearly inaccessible.

2dly. They may be accessible, and yet so steep that they cannot be defended by the direct fire of artillery.

3dly. They may be gentle, in the form of a glacis.

124. When the heights are nearly inaccessible, works of slight relief should be constructed on the most salient points, and instead of forming a ditch, the slopes may be scarped, as represented in Figs. 54 and 55, flanked by artillery placed at the re-entering angles of the ridge. The notches in Fig. 54, cut in the original slope, are intended to prevent the newly raised earth from slipping. The parapets of works situated as above-described, unless commanded by the ground in front, would not require to be more than 4 or 4½ feet high; their crests should be brought as near as possible to the brow of the hills; and when not liable to be cannonaded, dry stone walls may be advantageously substituted for earthen parapets. Small works similar to a redan, and called *flèches*, should be constructed (if the ground admit thereof) in front of, and immediately under, the fire of the principal works; both to discover those parts of

the ground which are concealed from the view of the latter, and to afford cover for guns, placed there to flank the approaches to the collateral works.

The earth excavated to form a terreplein for the guns will supply that required for the parapet of the flèche, which differs from a redan only in having no ditch.

125. In the second case, if the table-land present no salient angles, the works to contain the artillery should be placed in such situations as will enable it most effectually to defend the approaches to the foot of the hill; for, as a piece of ordnance mounted on a common carriage cannot be fired under a line inclined 10° below the horizon, the ascent of the hill could not in this case be defended by the fire of artillery.

On the crest of the hill, works for musketry should be thrown up, open at the gorges, that the troops may deploy and attack the enemy in flank, if he mount the hill between those works. The defenders then act with all the spirit of assailants, and have the advantage of contending with troops already partly exhausted by their previous exertions.

126. In the third case, which is the most frequent, the works should have a good profile, and be so disposed as to obtain cross fires on the slopes of the ground over which the enemy must pass; and in this case, as well as in the first, the works should occupy the crests of the hills.

When the crests of the hills are of no great

extent in width, the communications between the several works should be made on the reverse slopes of the heights, where they will be perfectly screened from the view of the enemy. In parts exposed to his view, cover may be obtained by excavating a trench similar to the first parallel made in a siege, Fig. 152.

If in rear of the position other more elevated points are occupied with works, you must endeavour to trace the front line of redoubts or other works in such a manner as to expose their interior to the view of the works in the second line.

If the ground be occupied with detached works, they must either be sufficiently near each other to prevent the enemy passing between them, or must be capacious, and contain powerful garrisons; otherwise he would proceed at once to assault your second line, and thus render the first useless.

When the works in the first line are commanded by the ground in front of them, and the ridges of the hills are narrow, the salient angles should be placed so as just to shew themselves over the crest, and the interior of the works be laid out on the reverse slopes of the heights.

The works thus traced will be more easily defiladed than if traced in any other manner.

127. If it were required to occupy two heights within range of each other, and to close the valley between them, a redoubt of a good profile should be placed on each of the heights, and they should be connected by an indented line, gradually receding as it descends towards the bottom of the

valley. The prolongations of the faces of the indented line should be thrown on the redoubts, or pass in rear of them; and as they could only be obliquely battered by artillery, the parapets might be made proportionably slight. The flanks would, from their direction, be necessarily exposed to enfilade fire, but being short, this would not be any great inconvenience. If instead of thus adapting the outline of the intrenchment to the form of the ground, the valley were closed by a parapet traversing it in a right line from one redoubt to the other, you must either throw up a parapet of great height, or consent to be exposed to the view of the enemy, by giving it only a common relief.

128. It may be required to construct works on the middle of a slope ascending or descending towards the enemy. In this case the most level parts which the different undulations of the ground may present, should be carefully sought for, in order to place the parapet on their bends: however slight the different inclinations of the slope may be, the advantage of this selection will be sufficiently apparent when the work is commenced. If the enemy be placed at the bottom of the slope, the interior of the work should occupy the platform; if on the height, this platform should form the glacis.

These two arrangements, shewn in Fig. 56, are advantageous, inasmuch as a parapet of small relief will afford good cover to the interior of the intrenchment. In the first case, the superior slope

may be made as much as ¼; and, in the second, it may take, according to the slope of the hill, a contrary inclination, and be directed towards the interior of the work: this is necessary to resist the plunging fire, which would otherwise soon beat down the crest of the parapet.

129. It has been found by experience that an extraordinary degree of security is given to the artillery in open action, when placed on a very steep brow or bank of earth. Shot striking short, have as little effect against it, as those which are too much elevated, and the chances of being injured are very greatly diminished.

Parapets for musketry may be constructed on the slopes in any favourable points, as described in the last article. The artillery in this case should occupy the crests of the hills; and if their height be great, it may only be necessary to level a terre-plein for the guns, which would be sufficiently covered by the brow of the hill, when they recoiled, after the discharge, on the platform prepared for them. The artillery so situated may not be able to see the foot of the hills, but its plunging fire would greatly annoy the attacking columns while yet at a distance.

130. Sometimes in mountainous countries it may be necessary to construct parapets on slopes, so steep that no ditch can be excavated.

The earth for the parapet must then be taken either from the front or rear, as in Fig. 57. These parapets without ditches would be of little or no value unless they received a good flank defence of

musketry, or were protected by some natural impediment. If the materials can be procured, an abatis may be added, laying the branches on the slope, previous to the formation of the parapet, with which it would afterwards be covered, Fig. 57.

SECTION II.

ON DEFILEMENT.

131. The surrounding heights do not less contribute to modify the outline and relief of works, than the irregularities of the ground on which they are thrown up.

The object of defilement is so to regulate the relief of the parapets or covering masses, that the defenders may be perfectly screened by them from the view of the enemy.

The direction of a shot is supposed to be a right line drawn through the axis of the piece, and the point aimed at, for though projectiles move in curves, yet if a point be not seen, it cannot be battered at a point-blank range, with a full charge.

132. If on a horizontal site, the parapet of a work require a command of 8 feet, it must be evident, that, on an irregular site, if the crests of the parapet were placed in a plane parallel to the line A B C, Fig. 58, and 8 feet above it, the interior of the work would be as well covered

from *the point of command* C, in this latter case, as in the former. The line A B C is the trace of the *plane of site* as seen in a vertical section, and the corresponding parallel plane D E F is the *plane of defilement*.

133. When works are placed within range of heights by which they are commanded, the choice of the outline should be principally attended to; for, among the different tracings which may be used, some will be much more easily defiladed than others.

When a work is thrown up in front of a height, it is the more difficult to defilade in proportion to its depth; it should, therefore, be given an oblong form, and its longest faces be traced parallel to the height. If, for instance, the work were a rectangular redoubt, the long faces should be traced parallel to the height, and the short ones be directed on it. In selecting the site of a work as above described, if it be defended by works in the rear, or cannot be taken in reverse by the enemy, those slopes should be sought for, which if produced, would pass above, or be a tangent to the ground in front, as in Fig. 58, and on them the interior of the works should be established.

134. It may be laid down as a general rule, that the prolongations of the principal faces of a work, should be directed on valleys, or on parts where the enemy cannot place his artillery, within a distance of 600 yards of the salient angle of the work.

It would rarely be possible to direct all the

faces of a work so as equally to avoid the neighbouring heights: some of them generally will be exposed to slant, or reverse fire.

Works open at the gorge, such as lunettes, are the most easily defiladed: in others, it is often necessary to construct traverses to screen the rear lines from the view of the enemy. When the covering mosses are intended to protect the defenders from reverse fire, they are called *parados*. When open works require to be supported from the rear, or are used to cover bridges, roads, or dams, &c. they ought to screen as much as possible of the ground in their rear, or of the bridges, &c. they are intended to protect.

On the Practical Methods of Defilading Field-Works.

135. The first operations of defilement are, to determine the extent of the exterior space from which it is necessary to be defiladed, and the height of the plane of defilement, above the plane of site.

In permanent fortification, the horizontal limits extend to 1500 yards from the most salient works, the vertical limit or height being 8 feet.

In field fortification, the limits are regulated by the range of field-artillery and musketry, and by the height at which these arms are usually fired above the ground: for the former, the horizontal limit is 800 yards, the vertical one 4 feet, being nearly the height of the axis of a field-piece; for the latter, the limits are, horizontally, 300 yards,

vertically, 8 feet: whence it follows, that in the first case the terreplein should be 4 feet below the plane of site, and in the second case they coincide.

136. When a work is to be defiladed from artillery, the plane of defilement A C, Fig. 59, should pass 4 feet above the point H, and 8 feet above the point B, taken near the gorge of the work to be defiladed.

The plane D H, Fig. 59, parallel to the plane of defilement, and tangent to the point of command H, may be considered as the plane of site. This plane intersects the vertical line A B in the point D, 4 feet above the level of the ground.

It is required then to find practically a plane which shall contain the point D on its surface, and be a tangent to the point H. The following method of finding the required plane is general, and applied in this example to a lunette.

137. After having planted poles at all the angles of the lunette, Fig. 60, and stretched a cord *m n* four feet above the gorge line, hold a straight edge *a b* between two pickets driven a few yards in rear of the work; elevate and depress the straight edge, until the lines *m n* and *a b* are both in a plane tangent to the height H.

If then the eye of the observer be placed at any point of the line *a b*, the visual ray E H, drawn on that plane through the pole at the salient angle of the lunette, will shew the height of the plane of site at the point C. In a similar manner the point D, at the angle of the shoulder,

or any other point required, may be found. To each of the heights so obtained add 4 feet, and saw off the poles at that height; their summits will then shew the height of parapet required, which should generally be less than 12 feet.

The first method of reducing the relief, if it exceed the maximum allowed, is to lower the line *m n* 1½ feet, which will still leave a relief of 6½ feet at the gorge. If this be insufficient, recourse must be had to traverses, or the ground be lowered at the gorge, which in some cases might be the least laborious operation.

138. When the points of command are within 300 yards of the work, the plane of site must pass through the foot B, Fig. 61, of the post placed at the gorge of the work; for the height C H, from which it is then necessary to be defiladed, is equal to that (A B) of the parapet at the gorge.

The plane of site passing through B and H would be very difficult to determine in the manner before described; but, if we suppose it to pass 1½ feet above the ground at the gorge, the observer will then be enabled to ascertain the direction of that plane, as in art. 140. Instead of setting off 6½ feet on each of the poles planted at the angles, to determine the plane of defilement, set off from 7 to 7½ feet on the pole planted at the salient, above the plane of site, and the work will be well defiladed.

139. With the aid of a plain table, the plane of site might be more accurately determined. If the upper surface of the plain table were placed

in a plane tangent to the points of command, the intersections of that surface prolonged, with the poles planted at the angles, would shew accurately the heights of the plane of site.

140. If it were required to be defiladed from two, or more heights, then the plane of site being at once tangent to two points of the surrounding ground, could not be made to contain on it a given line at the gorge, as in art. 140, but only a point of that gorge; for instance, a point near the centre of it, which point must be raised 4 feet above the ground when it is required to be defiladed from artillery, and 1½ feet when from musketry.

Let H and N Fig. 62, be two heights from which it is necessary to be defiladed from artillery. In the centre of the gorge of the work, or at the point most distant from the given heights, plant a stake projecting 4 feet above the ground. In front, place two other stakes D and E, and cause a straight edge to be moved up and down on them, until, when seen from the end of the first stake, it appears to touch at the same time both the points H and N. The plane thus found will evidently be the plane of site; and to the heights obtained by it 4 feet are to be added, as before.

Instead of a straight edge A B, a tape or cord may be made use of, which must be kept stretched tight by a person at each end, who slide it up and down the stakes D and E, until it appears in the plane of site.

141. It often happens, in the case above described, that a single plane of defilement would

give too great a relief; the left part of the work must then be defiladed from the height H, and the right part from the height N.

This method exposes the faces to be enfiladed, or seen in reverse, and will consequently render it necessary to erect a traverse to cover them. The traverse is usually made on the capital; and its height should be sufficient to screen the troops, when mounted on the banquette, from the view of the enemy.

The thickness of the traverse at the top, should not be less than 6 feet, if intended to resist artillery. Its slopes, unless revetted, are left at 45°.

142. A triangle of about one yard each side, constructed of smooth laths, the ends halved into each other, so that the upper and under surfaces may be parallel, is sometimes used to find the planes of site.

If a line at the gorge, as *m n* Fig. 60 be given, place one side of the triangle on this line, and move the apex until the surface of the triangle is a tangent to the commanding point.

If a point near the gorge be given Fig. 62, place one of the angles of the triangle on the given point, and move the triangle about that point, until its surface is a tangent to the points of command.

143. An enclosed work constructed on the slope of a hill, having a plain on one side, always requires a traverse to cover it from the slant, or reverse fire of the plain; so that a plain is as dangerous to a work constructed on the slope of a

hill near it, as the hill would be to the same work constructed on the plain.

The most simple mode of determining a traverse is to assume its position, and then give it a sufficient height to cover the men placed on the banquettes on each side of it. At the same time, the planes of defilement of the parapets should pass 8, or 6½ feet at least, above the ground towards the centre of the traverse.

144. Let A B, Fig. 63, be the central line of a traverse, and C D, E F, the two opposite parapets of a redoubt, to be defiladed from musketry. On the side of the plain, the parapet E F would be made 8 feet high; but the height of the parapet C D, on the other side, must be so regulated that the plane of defilement may pass 8 feet above the ground, in the direction of the axis of the traverse.

Then find the lines of fire P *c*, M *e*, which must be 2 feet above the parapets D C and E F, in order that the shot may be intercepted by the traverse, or pass over the heads of the troops mounted on the banquettes. The height of the traverse is then determined by that line of fire which gives the greatest relief.

For the first of the two lines P *c*, M *e*, plant at the point L a pole 8 feet high; measure on the pole D C of the profile of the parapet, C *c* equal to 2 feet: the visual ray passing through the points P and *c* will be the line of fire sought.

The other line of fire may be determined in a similar manner, or thus:—From the point *f*, 6 feet below E, find a tangent to the commanding

point K: from the point b, where the visual ray fK intersects the central line A B of the traverse, add 8 feet, to find the height of the vertical A b.

Having thus found the relief of the traverse required to cover the widest part of the work, and its command over the parapets being known for that part, let the same be preserved throughout.

These constructions, though simple, require some time: when no opportunity offers of determining accurately the dimensions of the traverse, required to defilade a work, make it one yard higher than the parapet, and the work will, in most cases, be perfectly covered.

145. In a quadrangular work, the traverse should always be made on one or other of the diagonals, and also be parallel to the height, when the redoubt is constructed in front of one, and presents one of its angles to the height. See arts. 30 and 31, Appendix.

Defilement of Lines.

146. In the defilement of lines, as in that of isolated works, the object proposed is, to cover the interior space from the view of the neighbouring heights. To obtain this result the same means also are employed, viz. increased relief of parapets, excavation of terrepleins, and construction of traverses, parados, or bonnettes.

In addition to what has been stated in former articles, it may here be observed, that the space within which the defenders are covered by the works should be the greatest possible, the defence

of lines requiring large bodies of troops, formed either in lines or in columns.

The choice of a position to be fortified, as well as the particular method of occupying it, by continued lines, or lines with intervals, is, therefore, a matter of very great importance. If any of the commanding heights of a position cannot be occupied, epaulments may be thrown up 50 or 60 yards in rear of the lines, to cover the troops intended for their defence. Ramps may be made in rear of these epaulments, for the artillery and cavalry to pass over them; or openings must be left in the most convenient parts for that purpose. The epaulment may be given the form represented by Fig. 152.

It is in general not possible to place all the crests of continued lines in the same plane of defilement; they should then be divided into parts, separated by traverses, each part having its own planes of site and defilement.*

* For the scientific mode of defilading field-works, as taught in the Royal Military Academy at Woolwich, see Appendix, Note I.

CHAPTER VI.

DEFENCE OF RIVERS AND WATER-COURSES.

SECTION I.

OF BRIDGE-HEADS,* AND OBSERVATION OF THE BANKS OF RIVERS.

147. Rivers and streams play a part of consequence in attack and defence; they are, in ordinary circumstances, equally favourable to both armies—presenting to both an equal obstacle.

This reciprocity will cease, if, after having established bridges on the river, works are thrown up to protect them on the enemy's side. Then an opportunity is afforded of penetrating his country at pleasure, to carry on any offensive operations that may be required, while the bridges secure the retreat of the assailant in the event of a reverse. Every thing in this case favours the attack, so long as a communication with the works thrown up to cover the bridges is kept open.

These works are called *bridge-heads;*† their

* *Fr.* Têtes de pont.

† Military men generally yet use the French term.

general arrangement, and particular form, will vary according to the nature of the ground to be occupied, the shape and width of the river, &c.

148. The ground in front of the bridge ought, if possible, to be so occupied, as to cover the bridge from the fire of the enemy's artillery; the possibility of this being done depends altogether on the selection of site, in the choice of which many equally important objects require to be considered. The business of the engineer is to cover the bridge, as far as practicable, with few works, requiring small garrisons, that as great a number of troops as possible may be spared for the operations in the field, by which the fate of a campaign is in most cases decided.

From these considerations it would appear that a bridge-head, to cover an important communication, might be advantageously traced in the following manner:—At distances of about 250 yards apart, and 300 yards from the bridge, the salient angles of detached bastions may be placed: these bastions should be closed with a ditch and parapet at the gorge, forming a system of redoubts mutually defending each other. The head of the bridge should be protected by a good stoccade or tambour.

The redoubts completed, ditches may be excavated between them, and the earth thrown up be formed into curtains, traverses, and parapets to flank the ditches of the redoubts.

In this manner a defensive arrangement of works may be made, possessing all the advantages

of a system of bastioned lines, and requiring only to have three or four redoubts well manned.

Another mode of tracing a bridge-head would be to place lunettes, or detached bastions, mutually flanking each other, about 300 yards from the head of the bridge—their intervals and gorges being swept by the fire of a fort, constructed to cover the head of the bridges, and to afford a place of retreat for the defenders of the advanced works, if the enemy should succeed in forcing them.

By this disposition of works, the enemy's artillery will be kept at such a distance that no apprehension need be entertained of his being able to destroy the bridges. If the bridge-head be constructed at the re-entering angle of a river, the lunettes or detached works may be traced on a right line, or nearly so, which will both augment the value of the near defence, and diminish the development. In this case, also, the central work or fort may very easily receive a flank defence from batteries placed on the opposite bank, or on the islands which are frequently found at the bends of rivers. The flanks, also, of the advanced line of works would receive a similar defence.

These considerations are sufficient to point out that the best situation for a work to defend the head of a bridge, is at the re-entering angle of a river.

149. Instead of being parallel to the frontier, the river may be perpendicular to it, in which case both banks must be occupied by the

defenders, and a double bridge-head be constructed, which offers the great advantage of enabling you to oppose the enemy on either bank.

To derive the greatest benefit from a river under these circumstances, several bridges should be established on it; so that if the enemy were to succeed in cutting off the communication by any one of them, a retreat might still be open by another.

150. The detached works of a bridge-head should be constructed to contain about 200 men each, have their gorges defended by a good stoccade, and contain in their interior a small tambour or block-house of timber. The salients of these works may be placed at 300 or 400 yards apart; for if they have a good relief, and are, as they ought to be, well fraised or palisaded, they will not require such close support as those of the common line with intervals, described in art. 55.

Lunettes so constructed, with obstacles sufficiently multiplied about them, will, if well defended, render abortive any attempt of the enemy to carry them by assault, without having previously cannonaded them.

If the advanced works were incapable of making an independent defence, their garrisons would soon be driven from them; it is therefore desirable to give to those works every possible degree of strength.

151. The intrenchment covering the bridge being the most important work, must have the greatest care bestowed on its construction. It

will commonly be composed of one or more bastioned fronts, the wings flanked by batteries placed on the opposite bank. The entrances are left on the wings, about 20 yards wide, and covered by interior traverses. An interior intrenchment of wood-work should be constructed immediately in front of each bridge, more effectually to secure the bridges against the enemy's enterprises; who, even if he did succeed in forcing the principal work, might, with the aid of these last intrenchments, still be driven back, or at least be prevented getting possession of the bridges.

One or two batteries should always be placed to destroy the bridges, in the event of the enemy unexpectedly forcing the central work, and its interior intrenchments or stoccades.

In Fig. 84, a bridge-head is represented combining the several details above given.

152. It will sometimes happen that only one bridge is to be covered. In this case, the central work may be much less extensive, and be composed of a single bastioned front with long branches on its two sides, called a *hornwork*, or consist only of a large double redan, or lunette, defended from the opposite bank, Fig. 85.

These latter arrangements are frequently made, when the small width of the stream, and nature of the ground, permit the head of the bridge, and the works covering it, to be well defended from the opposite bank. As to the dimensions of such works, nothing fixed can be laid down; they must vary with every new situation.

Observation of the Banks of Rivers.

153. The possession of the bridges on rivers is as favourable to the attack as to the defence. Whatever, therefore, may be the attitude of an army, all the bridges in its possession should be covered by intrenchments; but it is also necessary, when acting on the defensive, to watch the fords, and be in a situation to dispute the passage of a river, wherever it presents a favourable point for that purpose.

In front of fords, the general outline of the works should be concave, and batteries should be erected, to rake and flank the ford. The principle on which the works are to be traced, is, that the enemy should be exposed to an enfilade fire where the ford is straight, and also to a converging fire, when forming or deploying, after passing the stream. If the space enclosed by the works be favourable to the movements of cavalry, intervals should be left to facilitate their egress from the intrenchments. If the river be wide, and the ford narrow, a redoubt, or lunette, or a field battery, may be sufficient to defend the passage. A field battery* consists of a parapet pierced with embrasures, with epaulments on the flanks, and traverses in proportion to the extent of the battery, to cover the guns from enfilade fire.

154. The salients of a river, corresponding to the re-entering angles formed on the enemy's side, being, for the reasons stated in art. 148, the most

* The artillery accompanying an army in the field are divided into batteries, also called field-batteries.

favourable points for establishing his bridges, works should be thrown up for their defence, the form of which will depend on that of the ground, the width of the river, and nature of the heights which may happen to be within range of artillery.

A good redoubt will commonly be the best work to oppose the efforts an enemy may make to establish his bridges. Sometimes to occupy all the space, one or more bastioned fronts may be required; and in advance of each, a lunette may be placed, the better to discover the banks.

In order to give as great a saliency as possible to these lunettes, they may be thus traced: After constructing the bastioned front Fig. 86, join the middle of its faces A and B by a right line, and on this line as a base describe an equilateral triangle A B C: the apex C of the triangle will be the salient angle of the lunette, and the lines CB, CA, shew the direction of the faces, which may be made equal in length to those of the bastioned front.

The ditches of the faces of the lunette should terminate towards the flanks in gentle slopes, directed on the crest of the parapet of the demi-bastion in the rear, in order that they may be seen into, and defended by the faces of those demi-bastions.

155. The water-courses separating armies are not always rivers, or great streams; they are often rivulets of such small width as to permit of works constructed on one bank, defending the approaches to the other.

Such a stream should be observed throughout the whole extent of the position, and be defended by detached works placed in the most favourable situations to flank each other, and at the same time give a cross-fire on the fordable points,—for the better defence of which, a close, and direct fire of musketry should likewise be obtained. A rivulet in this case would perform the part of a wet ditch covering the position.

156. When, on account of the commanding heights, the works cannot be placed sufficiently near the banks of the river to defend it well, posts of observation should be established as near those banks as possible; and if the ground be low or marshy, or a portion of the stream can be diverted through it from a higher level, the space in front of the works should be intersected with small ditches.

SECTION II.

OF INUNDATIONS AND DAMS.

157. It does not always happen that an army acting on the defensive can find rivers or streams to cover it: we must know how to derive advantage from the smallest rivulets the country affords, retaining its waters to form inundations.

It rarely occurs that the means provided for the execution of field-works are sufficient to allow of a dam being made more than 10 feet high; the difference of level between any two dams would in

this case be 5 feet, in order that the shallowest parts of the inundation may not be fordable. After having determined the position of the first dam, that of the others may be found by levelling, or from the information collected from the millers of the neighbourhood, with respect to the fall of the stream.

The axis or central line of the upper surface of the second dam should be placed 5 feet below the first, the axis of the third 5 feet below that of the second, &c.; so that the distances of the several dams from one another must be determined by the slope of the ground. It follows, then, that this kind of defence is rarely applicable to mountainous countries; it is also inapplicable in extended valleys, unless the banks of the stream are high, and within a moderate distance of each other; otherwise the dams required to retain the waters would be too extensive, and be difficult to defend. No limit can be assigned for the greatest length which may be given to a dam. In one case a dam of 100 yards in length would be a gigantic undertaking, while in another the construction of such a dam would be a work of trifling consideration, as compared with the advantages obtained.

158. The profile of dams, and of their waste weirs, does not depend on their length, but on the depth of water to be retained, and its exposure to cannonade. The details of construction most commonly adopted for them may, therefore, be pointed out.

If the dam cannot be battered by artillery, it

should be made 5 feet thick at the top when formed of earth. The earth of the dam should be taken from below it, in order to give a greater depth to those parts.

If the earth in the immediate vicinity of the dam will not bind sufficiently to prevent the filtration of the water, a proper soil must be obtained in the neighbourhood, and embedded in the dam. The best method of preventing filtration is to construct the interior of the dam with well-tempered clay, called puddling. In some cases the alluvial soil in valleys will be found to be of great depth; it then becomes very difficult to dam up the waters. If the soil be of a sandy nature, it is not fitted to retain an inundation. When sites of the above description are met with, the bed of the valley or ravine should be thoroughly examined, and the construction of a dam should not be undertaken, unless ample means of execution be provided to ensure success.

When the dam is to resist artillery, it must be made 10 feet thick at the top. The exterior slope of the dam may be left at the natural slope of the earth, while, to the interior one, a base of not less than double its height should be given, that it may more effectually resist the pressure of the waters of the inundation.

159. If after constructing a dam of earth, as above described, the water were suffered to accumulate, and flow freely over every part, it would soon be destroyed, however small the velocity of the stream.

To prevent this, one portion of the dam is left lower than the remainder, and of a sufficient width to give a free passage to all the waters of the stream, or a cut is made round one end of the dam for that purpose.

The surface of the part over which the water is permitted to flow is formed in a more solid manner than the rest of the dam, and is called the *waste-weir*.

The waste-weir is constructed with fascine-work, Fig. 87, or with timber and plank.

After having raised the dam to a height of 1 foot 6 inches less than that required for the upper surface of the waste-weir, a double revetment of well-picketed fascines is commenced, which revetment should not only cover the top of the weir, a portion of its interior, and all its exterior slope, but extend also along the bed of the lower inundation or stream, that the rush of water over the weir may not form pits near the bottom of the dam.

The horizontal fascine-work below the dam should be let into the earth, and be made wider than the rest of the weir. To give greater solidity to the fascine-work, the pickets should be permitted to project above it, and stout twigs be interwoven among them, so as to form a species of hurdle-work above the fascines. A much greater number of pickets must be used for work of this description than for common fascine-work, and these pickets should not be less than 5 feet long. The cheeks of the weir, or lateral parts of its opening, are

likewise revetted with fascines, laid across those forming the bottom of the weir, and firmly picketed to them. There should be four rows of these fascines, so as to cover the ends of the horizontal fascine-work about 3 feet.

160. To construct the dam, begin by forming the two extremities, leaving the middle open, to give a free passage to the waters until the remainder of the dam and the waste-weir are completed. Then fill up the bed of the stream, taking care to connect the new earth well with the parts first executed, and complete the dam.

161. When works are covered by inundations, it may happen that it is desirable to secure the means of letting off the waters at pleasure. This may be done by means of sluices constructed of wood-work.

The sluice may be made with gates, or consist of pieces of well-trimmed timber, grooved and tongued into each other; two stout pieces of scantling being secured to each side of the sluice, to take their ends. This latter arrangement can only be used where the stream is small.

Having a sluice constructed in a dam does not do away with the necessity of a waste-weir, unless the body of water be so small that it may be allowed to flow freely over the gate, or the dam be constructed entirely of wood-work, in which case the sluice-gate may be made to form a part of it, opening at the bottom, in a manner similar to the openings made in the gates of locks; the water will then find a passage under the inclined plane

of wood-work forming the superior surface of the dam.

Whether gates or sliding timbers be used, the sides and bottom of the sluice for temporary purposes should always be made of wood-work. Fig. 88 is the elevation of a sluice-gate, worked by two levers. The pieces of timber *a*, laid across the sluice-gate for the manœuvre of the levers, may serve to form a small bridge, when it is wished to make a common passage of the dam.

162. The waters of an inundation require more or less time to rise to the level of the waste weir, in proportion to the velocity of the stream, its vertical section, and the capacity of the inundation. The engineer should, therefore, ascertain these points, in order not to be deceived in his expectations, and to know, what length of time will be required to extend the inundation.

To calculate the produce of a stream running in a uniform manner, multiply the mean velocity of the stream by the transverse profile, viz. by the section of the water formed in its passage through the sluice.

The experiments of Dubuat shew, that to determine the mean velocity of a current, when we know the velocity at the surface, V being this velocity in inches, and V′ the medium velocity sought;

$$V' = \frac{V + \sqrt{\overline{V} - 1}^2}{2};$$

in which expression $\sqrt{\overline{V} - 1}^2$ is the velocity at the bottom of the current.

If, then, S be the area of the section of the water-course, T the time sought, and C the capacity of the inundation, we shall have

$$V' T S = C$$

Whence $$T = \frac{C}{V' S} = \frac{2 C}{S(V + \sqrt{V - 1^2})}$$

T will be the time in seconds; C, S, and V, should be measured with the same dimension, cubic, square and lineal.

163. The end of the dam on the enemy's side, must be protected by intrenchments, to prevent his destroying it, or using it as a bridge.

When no work can be placed, as will sometimes happen, immediately to cover the head of the dam, the approaches to it should be defended; or if the opposite bank be within a short musket-range, the end of the dam may be covered by an abatis. Small islets are often formed in the midst of the inundations, on which batteries and parapets for musketry may be advantageously thrown up, either to protect the dams, or for the general defence of the position. When plenty of heavy timber can be procured, a raft-bridge may be made to communicate with these detached works; or an enbankment may be thrown up for that purpose, 10 feet wide at the top: this might in many cases be a work of great labour, but it rarely happens that an inundation is more than 400 or 500 yards wide, and it is then only that it becomes necessary to occupy the islets. The works thrown up to cover the head of a dam,

should be traced on precisely the same principle as those for the protection of a bridge.

The best position for a dam, therefore, when a matter of choice, would be where the opposite bank of the inundation formed a re-entering angle.

CHAPTER VII.

PASSAGE OF RIVERS.

164. The passage of a river in the face of an enemy is one of the most important operations that an army can be called on to execute.

It may be performed either by open force, or by stratagem. In the first case, you drive the enemy as far as possible from the opposite shore, by a brisk cannonade, then push over in boats a sufficient force to keep him in check, during the construction of the bridge.

165. In the second case, superior forces are to be assembled on one or more points of the river —carriages and boats are to be collected—batteries thrown up—and, in short, every possible demonstration is to be made, to persuade the enemy that a passage will be attempted at one of those points.

When he has concentrated his forces to oppose the anticipated attack, the pontoons, or boats, may be removed during the night to a distance of some leagues, and be ready for throwing over the bridge at the dawn of day. Field artillery accompany the pontoon train, and take post on the banks of the river, so as to obtain a cross-fire on the ground in front of the intended bridge. As great a number of troops as possible are immediately passed over,

to occupy every favourable point of the opposite bank, and drive off the enemy.

Extra pontoons, or boats, should be provided, to be continually employed in the passage of troops to aid those first pushed over, who take possession of any houses, gardens, or other points capable of being artificially strengthened, close up all front and lateral openings, break open communications with their rear, loop-hole the walls, and, in short, do all they can to strengthen their post.

As soon as the bridge is completed, the engineers proceed to trace the works intended for its defence. At the same time that the troops are engaged in effecting the passage of a river, one or more feigned attempts should be made at other favourable points; and be persevered in, with the semblance of obstinacy, if it appear that the enemy has been deceived as to the real intentions of the assailant. The main body of his forces may thus be retained at a distance from the point of passage, until a sufficient number of troops have passed the river to ensure success.* It may be confidently relied on, that an army provided with a good pontoon train cannot be prevented effecting the passage of a river, if that army be skilfully commanded.

166. The choice of the point at which to pass a river is a subject involving many important considerations, often at variance with one another.

* See Relation du Passage de la Limat, par Dedon. Paris, 1801.

The re-entering angles formed by the windings of a river are those most favourable to the assailant, not only because the bridges once constructed will then be more easily covered by the works thrown up to protect them, but also because the batteries which support their construction will give a more effective cross-fire on the enemy's shore.

In the great elbows of rivers the current is less rapid than in other parts; and small islands are frequently found there, which facilitate the construction of the bridges, as well as their defence when completed. Choose that part of a river near which bays or inlets are formed, or where another stream emptying itself into it, presents a situation in which you may launch your pontoons, or boats, out of view of the enemy, and whence you may proceed with the current to the intended point of passage. One very influential point in the selection for the passage of a river will frequently be the nature of the roads, by which the pontoon train is to travel to get to the given point, or to some spot at no great distance, from which the pontoons, &c. may be carried by a working party to the bank of the river.

Observe whether the opposite bank be easy of access, whether lower or higher than on your own side, capable of being defended by batteries on your bank, or the contrary; whether intersected with woods, copses, hedges, walls, or ditches, or otherwise affording cover, which may enable the troops first passed over to keep the enemy at bay,

whilst the extra pontoons, or boats (formed into rafts), transport others to their assistance.

Ascertain, if practicable, whether the anchorage be good; for if it be not, great difficulty will be found in establishing the bridges in a secure manner.

Of Military Bridges.

167. Any description of bridge that can be speedily constructed, and for the materials of which the means of transport can be provided, may be properly termed military. In general, a military bridge consists of supporting bodies, *i. e.* either pontoons,* boats, casks, or floating masses of timber, placed parallel to the banks of the river, at a greater or less distance from one another, in proportion to their strength or buoyancy, and the weight they are required to sustain.

These floating bodies, serving the purpose of piers in permanent bridges, are connected by pieces of timber called *balks*, which being covered with planks called *chesses*, form the superstructure or floor of the bridge. The space between two supporting bodies, together with that occupied by one of those bodies, is called a *bay*.

The weight a bridge may be required to sustain, is the first point to be considered.

Infantry, in two ranks, occupy a space of 3 feet in depth: we may therefore assume, that in

* Pontoons are of various forms: the old descriptions were flat-bottomed open boats; the new ones proposed to supersede them, are decked canoes of copper, cylindrical wooden buoys, and tin cylinders.

passing a bridge formed four deep,* not more than eighty men will be supported on 40 feet lineal of the bridge. Supposing each man, with his arms, to weigh 200 lbs. on an average, then 16,000 lbs. is the weight to be supported by that length of bridge. If cavalry pass in file, 40 feet of the bridge will have to support eight horses, and eight men; suppose each horse and man together to weigh 1400 lbs., then 11,200 lbs. would be the weight of cavalry † on 40 feet lineal of the bridge.

A 12-pounder gun, carriage, and limber, weighs about 45 cwt.: the bearing points of the wheels of the gun and limber are 9 feet apart; the whole gun, together with the horses, occupying a space of about 40 feet in length; but the weight of a

12-pounder, carriage, and limber, is	5040 lbs.
6 horses	6048
3 men	450
	11,538 lbs.

40 feet lineal of the bridge will, therefore, have to sustain,—with

Infantry, four deep	16,000 lbs.
Cavalry in file	11,200
Artillery, 12-pounders	11,538

* Infantry should never be allowed to pass a bridge formed more than two deep, except the bridge be a very short one; neither should they be permitted to keep step while crossing a floating bridge.

† Cavalry should never cross a floating bridge mounted, if it can be avoided.

A bridge calculated to support infantry i deep, may, therefore, be passed by cavalry in i and by field artillery.

The difference of weight between the pounder, &c. and infantry, is required as an all ance for the unequal distribution of the weigh the former on the bridge.

The number of supporting bodies necessary form a bridge, of any given length, will depe 1st, on the buoyancy of the body itself; and, 2 on the scantling of the timber which can be p cured for balks.

When boats are the supporting bodies, take mean length, breadth, and depth, above the wa line, subtract from the last dimension 6 inches a foot, or such other dimension as the gunw may be required to remain above the water, wl the bridge is loaded with its greatest weight, wh dimension will depend on the rapidity and m nitude of the stream.

Multiply together the mean length, bread and corrected depth; then each cubic foot of product will support a weight of 62 lbs.;* fr the buoyancy thus found must be subtracted weight of the superstructure required to be bo by each boat; the remainder will be the availa buoyancy of the bridge.

If the boats are small they may be connec together in pairs. When large boats only can

* The specific gravity of the water to be displaced b 1000 ounces per cubic foot.

procured, and but few of them, bridges may be formed with cables stretched across the river, and supported by these large boats or vessels, in the manner described in the second volume of Jones's "Journals of the Sieges in Spain," p. 104.

The disadvantage of a bridge of this latter description is, that it cannot be partially dismantled, to permit the passage of any floating bodies, sent down the stream by the enemy, to destroy the bridge. Booms must, therefore, be stretched across the river, to arrest the progress of those masses.

168. Carts or wagons may often be used as supporting bodies for a bridge, over a canal, or river of small depth.

Each pair of wheels with their axle may have a trestle attached, on which to lay the floor of the bridge.

Timber carriages are well adapted for the formation of a bridge, where the depth of water is nearly uniform, and not very great, as, for instance, over canals.

169. A flying bridge consists of a large boat, or raft composed of two boats, anchored with a long cable, and which is carried from one bank to the other by the current.

170. Raft bridges are easy of construction, since they consist only in securing together stout pieces of pine, or other light wood, and covering them with planks or boards; but rafts thus made are not capable of bearing great weights; they are not, therefore, fit for the transport of artillery.

Small bodies of cavalry may be passed over

bridges of this kind; the men dismount, and lea their horses in single file, keeping a moderate di tance apart.

The buoyancy of a raft may be increased, b lashing empty casks to its side, or under it. With the aid of a small pump, a cask may be easil introduced under a raft, by first filling it wit water, and then having secured it in its bertl pumping out the water through the bung-hole.

171. Cask bridges are made by lashing tog ther a sufficient number of casks to form a pie for the bridge, which is then divided into bay The number of casks requisite for each pier wi depend on their size, and the buoyancy require to be given to the bridge. Casks may generall be procured in the neighbouring farm-houses, villages; the floors and roofs of which, will fu nish materials for your bridge, if no better are hand.

172. Trestle bridges can only be used for th passage of rivers of small depth, and the bed which is not very uneven. The trestle may b similar to those described in art. 91, an additiona leg being added to the end placed down the stream to enable it the better to resist the current: thi leg is armed with an iron point, the upper en being secured with a hook, to a ring, passing ove the end of the transom. The trestles should b 10 feet wide; five joists or balks are laid acros them, their scantling about 7 by 5 inches; th joists are covered with plank, and side-rails ar secured with rack lashings to the extreme balk

as described in art. 91. The trestles should be placed 10 feet from centre to centre.

173. Pontoon Bridges.—For a description of the old pontoons, and the method of forming bridges with them, as well as for the details of raft and boat-bridges, and the mode of repairing bridges, &c. &c., the work of Sir Howard Douglas on Military Bridges should be consulted.

CHAPTER VIII.

ON MILITARY POSTS, AND WORKS THROWN UP ON THE EVE OF BATTLE.

174. When villages, hamlets, farms, or enclosures of any kind, are occupied by soldiers, and placed in a state of defence, they are called *military posts.*

The advantage which may be derived from an intrenched village in a field of battle, is too apparent to need a comment: a post of this kind, when properly defended, will oblige an enemy either to make great sacrifices to get possession of it, or altogether to forego the offensive operations he may have planned.

Many instances have occurred where a few brave men having obtained possession of a farm-house, or old castle, have defended themselves for a length of time against greatly superior forces. Every officer in the army should therefore be sufficiently instructed in fortification to place a country-house, farm, or village, in a state of defence.

Sometimes a military post forms part of an extended line, and is supported in the rear by the troops it covers; at other times, it is placed in an independent situation, and is left to its own efforts.

The post should, in the latter case, contain magazines of provisions and powder, because it may be required to defend it during a long period. In every case, temporary cover for the troops, and an interior intrenchment, are essential.

Villages commanded by the neighbouring ground, within musket-range, whose houses are much scattered, and which have numerous and wide spaces of ingress, can seldom be occupied with advantage.

Villages built of wood are ill adapted for defence, for they can be easily set on fire: those built of stone, the houses grouped together, and the gardens surrounded with walls or live hedges, are the best for military posts.

175. When an officer is detached to occupy a village, his first care should be to push forward his guards, and advanced posts, proceeding immediately to barricade all the entrances on the side of the enemy, excepting only a few small and concealed places of egress. He should next break up the roads by which the enemy can approach the post; have loop-holes made in all the walls of the gardens, or houses, his force may enable him to occupy; demolish, or burn detached houses, which would afford the enemy shelter, or mask the defensive flank fire; and fell all trees which when felled would obstruct the attack, or which if left standing would impede the defence. The artillery should be placed to defend those parts most favourable to the advance of the enemy. If intrenching tools are wanted, the officer will put in requisition

every thing of the kind the village or neighbourhood can provide.

While the soldiers, or peasants placed in requisition, are occupied with their first labours, officers are employed to make a detailed reconnoissance of the neighbourhood; others prepare a general plan of the works proposed to be thrown up, which, when approved of, should be immediately put in execution; reliefs of workmen should be provided, and not a minute be lost either of the day or night, until the system of defence is completed.

176. When the enemy has forced the exterior intrenchments, this first success should neither ensure to him the possession of the post, nor relieve him from the situation of fighting under a disadvantage. An interior intrenchment should therefore be formed: it will generally be the church and cemetery, or the strongest house in the village, if in an isolated situation, and placed so as to see the principal streets. This intrenchment should present an exterior defensive line, and an interior point of security.

Easy communications must be established between the interior, and exterior works. If in the immediate vicinity of the village there be any place which may be advantageously occupied, a communication should be made between it, and the village, either by a trench, a caponnière, or palisading; unless the detached post be at too great a distance from the village to receive an effective support from it, in which case it would necessarily become an independent point of defence.

Sometimes the village may not contain any building capable of being converted into an interior intrenchment; then the most favourable position in the neighbourhood should be occupied, with works of such a profile, as may ensure their being capable of making a good defence, after the village has fallen into the enemy's power.

177. In tracing the outworks of the village, advantage should be taken of the walls, hedges, and ditches, where they can be useful to the defence.

All walls and hedges within musket-range, behind which the enemy might conceal himself, should be destroyed, and all ditches parallel to the works be filled up, unless they are wet ones; observing always not to destroy any walls or hedges, &c. which will impede the enemy's flank movements, or check him under fire. In the interior, on the contrary, those walls which obstruct the lateral movements should be broken through, in order to open free communications, and for the same purpose bridges must be thrown over the ditches.

The hedges and walls preserved may serve as curtains to the principal intrenchments; sometimes they form the only defence, and then care should be taken to preserve those which flank each other.

If the village be traversed by a stream, advantage may be taken of it, to form an inundation: if the stream extend round the village, its waters may be retained by a dam, and protected by a small intrenchment.

Thus, at a small cost of labour, some portions of the village, or other post, may be rendered secure against surprise, and the greater force be consequently developed on the more assailable points.

A part of an enciente may be defended with an abatis, the ends loaded with heavy timber heaped up to form a parapet.

The abatis intrenchment offers, in a well-wooded country, one of the most simple and ready means of placing impediments to the progress of an adversary.

178. If the houses are thatched, the thatch should be taken off, because the enemy would otherwise easily set fire to them; and although by so doing he might not succeed in driving out the defenders, it would certainly contribute greatly to their embarrassment. Banquettes may be constructed with planks, doors, window-shutters, or other materials, on the upper row of beams or joists of unroofed houses, whence good marksmen might pour a destructive fire on the attacking troops.

179. The following means are to be employed to render hedges and walls serviceable to the defence:—If the hedge be more than 6½ feet high, cut off the branches to that height, and work in the parts so cut, to strengthen the remainder of the hedge; excavate a ditch in front, without being particular as to its dimensions or regularity of form, and let the earth be thrown over the hedge, and laid against it, so as to form a kind of parapet, of from

15 to 18 inches thick at the top; and with a portion of the earth a banquette may be made, to enable the defenders to fire over this parapet.

Sometimes you may not have time to make the arrangement above described; then dig a trench in the rear of the hedge, and form the parapet with the excavated earth.

If the hedge were planted on a steep slope, the earth should, as in the preceding case, be taken from the rear.

The hedge may not be 6½ feet high—then a small ditch should be made in front, the earth be thrown over the hedge, and a trench be dug in the rear to obtain cover behind the parapet. The earth of this trench, the depth of which must depend on the height of the parapet, may be used to give a greater thickness to that parapet, and to make a banquette. Or a trench may be dug in the rear of the hedge, 2 feet deep, and 3 feet wide at the top, and the earth be thrown against the hedge to form a parapet 2 feet high, behind which cover may be obtained by stooping. This trench might easily be excavated in half an hour, and would be of great assistance to light infantry. The hedge thus prepared should not be clipped, in order that the men behind it may be concealed from the view of the enemy, and that it may oppose a greater resistance to the assailants when endeavouring to force it.

Fig. 89 represents the five different arrangements above described.

A strong hedge thus prepared is an excellent means of defence. A thin hedge is but a very slight obstacle, and should therefore be avoided. Neither should those hedges be occupied which can easily be enfiladed by the enemy's artillery.

180. A wall 4 feet high may, without any preparation, serve as a parapet; but if it be 6 feet or more, loop-holes should be pierced. These loop-holes, when they can be given a regular form, as in mud or tapia* walls, are made as described in art. 123, and placed 3 feet from centre to centre.

Loop-holes generally are of an irregular form, pierced in the walls with pickaxes or hammers, and it rarely happens that you have time to make them in any other manner. They should then be made as small as possible.

To prevent the enemy closing on the loop-holes, a small ditch should be dug on the outside 2 or 3 feet deep, and the earth be laid against the wall. The depth of this ditch being small, its slopes may be kept very steep. If the wall be more than 4½ feet high, but too low to admit of loop-holes being formed in it, a banquette should be made, to enable the defenders to fire over the wall. The earth for this banquette may be taken from a trench excavated in the rear, in which the troops will be better covered, when not required to man the wall: in front of which a small ditch should be excavated—the earth spread abroad on

* *Fr.* Pisé.

he ground. Instead of making a banquette, the op of the wall may be cut down to form small mbrasures 3 feet apart.

181. With lofty walls two lines of fire may be btained, by forming a banquette of wood-work the tread 4½ feet below the crest of the wall), and iercing loop-holes on the level of the ground. The banquette may be supported on trestles, casks, &c., and be ascended by ladders, or stairs, made with the tables, stools, or other furniture of the eighbouring houses. To enable the defenders to ire through the loop-holes, the external opening f which must be very small, a ditch should be xcavated in rear, of about 3½ or 4 feet deep, and 2 feet from the wall. In this case no ditch must n any account be made in front of the wall, as it vould serve for cover to the enemy, and enable im to reap an equal advantage with yourself rom the loop-holes.

Fig. 90 represents the four arrangements last lescribed.

182. When a loop-holed wall is of great ex- ent, and in a right line, it would be desirable to lank it: for this purpose, tambours may be con- tructed, and the wall be broken through, to obtain n entrance into the tambour.

The form of these tambours may be that of a mall bastion, or simply of a redan: the salient ngle A ought to be of 60° (Fig. 91), that the aces A B and A C may give the most direct flank lefence possible. Towards the parts B and C, an blique direction should be given to the loop-holes

of the wall, to obtain a grazing fire on the faces A B, A C of the tambour. The interior of the tambour may be defended from loop-holes pierced in that part of the wall it covers.

Tambours are constructed with timbers 10 feet long, and about 6 inches square, which are placed touching each other, and sunk 3 feet into the earth. If the tambour be intended to give only one line of fire, the loop-holes must be pierced at the common height of 4½ feet from the ground, and a small ditch be excavated in front.

If two lines of fire are wanted, construct a banquette of timber and planks, 4½ feet below the crest of the tambour, then under this banquette pierce loop-holes on the level of the ground. In this case, for the reasons before mentioned, a ditch is to be dug in the interior, and not externally.

Tambours serve also, in certain circumstances, to cover the gates of communication with the exterior; then openings are left between the tambour and the wall, and these passages are closed by barriers, chevaux-de-frise, or loop-holed doors.

If the line of wall were so situated that its prolongation could be taken up by the enemy's artillery, traverses should be thrown up to protect the defenders from enfilade fire.

183. To form barricades, any thing may be used which can be procured. They may be made with carts sunk up to the axles, and filled with stones and earth; with casks filled in like manner; with trunks of trees, well connected together; with abatis, heaps of stones, rubbish, &c. It frequently

happens that the produce of the country furnishes ready means of forming barricades, or even parapets. In South America, the hides collected for exportation were used to form traverses; and in other countries, bales of cotton have been made use of for similar purposes. The best barricades are made with timbers laid across each other, forming square or oblong cases, which may afterwards be filled with earth or stones. A line of wagons drawn across a street, and the wheels on one side taken off, will be a sufficient impediment to the advance of cavalry, if a close musketry fire can be brought to bear on the barricade.

Banquettes should be made in rear of the barricades, to enable the defenders to fire over them: they may be flanked by loop-holes pierced in the walls of the adjoining houses, and openings should also be made in those walls to enable the defenders to pass round the barricades; or a passage may be left between the wall and the end of the traverse or barricade, closed by a barrier gate.

184. It has been stated (art. 176) that an interior intrenchment should if possible be formed, to increase the strength of the post by securing a retreat to the defenders. This intrenchment should be composed of an exterior enciente, and a well-prepared interior point of retreat. If the church is to be converted into an interior intrenchment, the walls of its yard are placed in a state of defence, in the manner already described; and in the interior of the church the following arrangements may be made:—The doors and lower win-

dows must be closed up, one entrance only being left; 3-inch plank, or other stout timber, the tiles with which the church is paved, or the tomb-stones, may be used to build up the several openings, leaving loop-holes in the masonry, which will be sufficient to defend the church, if, as is generally the case, it be built in the form of a cross, and that some openings are found on each face of the cross; then these loop-holes, though few in number, will, from their flanking each other, be of great value in the defence.

If the church be not built on a plan favourable to flank defence, the loop-holes in the windows will not be sufficient to defend it, for the enemy would then find shelter between them. In this case, loop-holes must be pierced in the walls throughout their whole length, if they are not more than 2½ feet thick.

A tambour should likewise be constructed on each side and end of the church, that every wall may be flanked with the fire of two or three muskets.

185. A last arrangement consists in constructing over ill-flanked doors a gallery *à machicoulis*, entered from a window or opening made in the wall for that purpose.

These machicoulis enable the defenders to throw down shells, grenades, or stones, on the assailants, and thus drive them from the doors, or foot of the wall; of which latter, they were the principal defence in ancient fortresses.

The machicoulis gallery is made to project

2 feet from the wall, in the clear, and has a musket-proof parapet of timber $3\frac{1}{2}$ feet high, Fig. 92. It is supported on brackets, the upper part of each passing through the wall, where it is internally secured to a transverse piece of timber, while the vertical part being applied to the wall prevents the bracket from falling forward. The brackets should be strong, and placed not more than 12 feet apart; they support two sleepers on which the floor is nailed, leaving between the boards spaces equal to their widths.

The machicoulis gallery is commonly placed on the level of a floor, or extrados of a vault, or aisle, in order that access to it may be more readily obtained.

Although the arrangement pointed out is sufficiently simple in itself, yet time and means are required for executing it, which cannot always be had.

186. The following is a substitute for a machicoulis gallery, which may be made at small expense and labour.

Commence by cutting away the wall to such a height that a man may be able to stoop and fire over it from the level of the floor, throughout the whole extent which the machicoulis ought to occupy, Fig. 93; then fasten to the wall with iron cramps a horizontal piece of timber, *a*, on which nail planks, *b*, placed at distances equal to their width.

These planks should be sufficiently strong to support a horizontal piece, *c*, to which they are

nailed; into this piece vertical timbers, *d*, are halved and nailed, and on them three planks are nailed—two on the upper part, and one below, to serve as a parapet for the protection of the troops when throwing stones or grenades on the assailants, through the openings left between the planks *b*.

187. If the enemy can, from a distance, destroy the church-door with his artillery, it may be protected by splinter-proof timbers, one end placed on the ground, the other against the wall, all touching each other, and then covered with from 5 to 6 feet of earth well rammed, or with earth in sand-bags.

These *blindages* serve also to shelter the troops from howitzer-shells in exposed parts: the soldiers find there the repose so necessary after fatiguing duties, or warm and obstinate combats.

In intrenchments intended to last for any length of time, the troops are lodged in a light kind of blindage, when plank for forming huts cannot be obtained; and these blindages being easily made musket-proof, may serve as a kind of defensive barrack. To construct them, excavate the earth 2 feet deep throughout the extent they are to occupy; stout branches of trees or rafters are connected to a ridge-board, kept at its proper height by posts. The branches or rafters are then covered with small brushwood, or fascines, and a layer of earth about 1 foot thick, over the whole of which a row of good sod-work is laid.

188. When a farm or country-house is to be

placed in a state of defence, commence by closing up the windows, and barricading the doors. These barricades, which can be overturned at pleasure, enable the defenders to get out of the house, and force through the enemy, if he has blockaded them; and thus make their escape during the night.

The walls should on every floor be pierced with loop-holes, to which a great slope must be given, that the enemy while advancing may be as long as possible exposed to the fire from them. The loop-holes on the ground-floor must be pierced 6½ feet above the earth, to prevent the enemy firing into them. The banquette, which may sometimes be necessary to enable the troops to use these loop-holes, may be made with planks supported on trestles, casks, &c. Under this banquette, a row of loop-holes should be pierced on the level of the ground.

If possible, a loop-hole should be made at every angle of the building, these being the weakest parts; but the cut stone, which is generally there used for quoins, is often an insurmountable impediment, where little time is allowed for the completion of the defensive arrangements.

When an external machicoulis cannot be constructed, holes may at least be made in the roof, through which projectiles of any kind that can be procured may be thrown over on the enemy. Unroof the building entirely if thatched: it would easily be set fire to, if this precaution were not taken; and in the defence of a house nothing is

so much to be dreaded: as a protection against it, the floors may be covered with moist dung, and barrels or tubs of water should be placed in every room.

The sleepers and joists which bear on the walls should be shored up, so that if the enemy batter the house with artillery, the partial fall of the walls may not of necessity be followed, by that of the several floors; which, when well supported, may be covered with a sufficient quantity of earth to render them splinter-proof.

Means of barricading any breach in the lower part of the building should also be provided, such as branches of trees, timber, or furniture of any kind.

There are few buildings altogether destitute of flank defence, and no opportunity of profiting thereby should on any account be neglected.

189. Behind the barricaded doors interior intrenchments of wood-work or furniture, &c. are to be made, and openings must be cut in the floors, through which the soldiers may fire down on, or bayonet the assailants: pitchforks, lances, or other simple weapons, may be likewise used for their annoyance.

If the house be surrounded by an enclosing wall, it should be prepared for defence in the manner described in arts. 180 *et seq.*

When the premises are very extensive, as will often happen, some parts may be little exposed to attack; in this case the strongest points should be isolated, by destroying the connecting galleries or

chambers; thus forming two or more distinct works, either of which may be held independent of the other.

Of Block-house Intrenchments.

190. In mountainous well-wooded countries block-houses are the best description of intrenchment, because the enemy cannot, in these situations, easily bring cannon to attack them, and it is very difficult in such countries, to find sites for works, free from the defect of being commanded in so great a degree, as to render the construction of open works almost useless.

Block-houses are commonly made rectangular, from 18 to 24 feet wide in the clear; but when they can be made in the form of a cross, Fig. 94, the flanking fire obtained on their faces will render them much more powerful.

A block-house may be assailable only by infantry, or it may be attacked with artillery; its profile in these two cases should differ.

191. In the first case, the block-house intrenchment should be similar to the defensive barrack, described in art. 119, its sides constructed of logs or squared timbers placed vertically, with loop-holes pierced in them 3 feet apart. The camp-beds serve as banquettes to the loop-holes. They are made $6\frac{1}{2}$ feet wide, with a slope of 10 or 12 inches from the front to the rear. The block-house should be about 20 feet wide, and 9 feet high in the clear: there will then be a free space of 7 feet between the beds. The logs for forming

the exterior of the block-house must be from 9 inches to a foot square, and about 12 feet long, so that they may be planted at least 3 feet in the ground. The tops of the logs should have small tenons to fit into a cap-sill morticed to receive them, or they may be placed horizontally one over the other, and halved or notched at the ends to fit close, in the manner the log-houses in America are built.

Girders of from 9 to 12 inches square should be halved and bolted into the cap-sill, to prevent the opposite faces of the building from spreading, and to support the roof. The girders must not be placed more than 12 feet apart.

On the girders joists are laid of from 7 to 9 inches in depth, and 6 or 7 inches apart in the clear; on these joists a floor of planks is laid, and the whole is covered with a layer of earth $1\frac{1}{2}$ or 2 feet thick. To prevent the enemy setting fire to the block-house, a ditch should be dug round it about 12 feet wide, and 6 feet deep, the earth partly laid against the block-house to form a parapet, as represented in Fig. 95, and the remainder formed into a small glacis. The escarp of the ditch should be traced at 10 or 12 feet distance from the block-house, to leave room for the base of the parapet. On the glacis, obstacles, such as abatis, military pits, &c. should be placed.

The provisions may be stowed on planks suspended from the ceilings, immediately above the foot of the camp-bed.

192. A block-house to resist the attack of

artillery, has two rows of timbers to form the sides, Fig. 96; the space between the timbers must be filled with earth, well rammed, as high as the loop-holes, making altogether a wall 3 feet thick. These block-houses should be 25 feet wide in the clear, and the girders, formed sometimes of two pieces, may then be connected together, as in Fig. 98, and be supported by an upright pillar in the centre, standing on a long block of wood, bedded in the ground. The girders should not be more than 6 feet apart, the joists should touch each other, and a floor of planks being laid on them, the whole must be covered with at least 2½ feet of earth.

The width of this block-house is sufficient to allow of a small parapet being constructed on the top, 4½ or 5 feet high, and 3 feet thick. The access to the platform is through a hatchway or trap-door. Under cover of the parapet good marks-men may be posted to fire on the assailants.

The platform above the block-house is of use not only at the moment of attack, but it enables the garrison, if closely blockaded, to get fresh air, cook their victuals, and better discover the enemy's movements.

193. A block-house may be constructed with less timber, by placing the upright timbers 6 or 8 feet apart, against the interior slope of the parapet, and covering them, as before described, with a cap-sill. The men will then fire between the cap-sill and parapet. Fig. 97 represents the exterior elevation of a block-house of this description.

The interior of this block-house would be similar to those already described, excepting that the interior slope of the parapet must be retained with fascines, or stout planks laid on edge, and resting against the upright posts. This arrangement saves wood and labour, but it is less solid, and the defenders are more exposed.

194. When not liable to the attack of artillery, very formidable block-houses may be built of two stories in height, the upper story projecting beyond the lower, or with its sides parallel to the diagonals of the lower story; the foot of which may then be well defended by the fire from above. A block-house of this description should be surrounded with a ditch to prevent a near approach.

The advantage of placing the upper story across the lower one is, that there would then be no undefended spaces, and that the enemy could not approach in any direction without being exposed either to the direct fire of one front of the block-house, or to a slightly oblique fire of two of its faces.

The timbers forming the sides of a block-house of this description should be laid horizontally one above the other, the ends notched out so as to halve into each other.

CHAPTER IX.

ON THE DEFENCE, AND ATTACK OF FIELD-WORKS, AND MILITARY POSTS.

On the Defence.

195. Having explained the principles to be observed in tracing, and constructing the various intrenchments which may be thrown up in the field, having shewn the arrangements necessary to be made, and the means to be employed for augmenting the strength of military posts, it now becomes necessary to point out some of the rules to be observed—in guarding and defending—or in attacking those intrenchments or posts. It has often happened that the vigorous defence of a military post, the possession of which might originally have appeared to be of little consequence, has either secured an army from entire defeat, or ensured its ultimate success.

The defenders of a post may be beaten, but they ought never to be found off their guard: their courage is put in requisition to prevent a defeat, their vigilance to avert a surprise; but neither their courage nor vigilance will much avail, unless both be skilfully directed.

Although the break of day be the moment when the vigilance of a commanding officer, is most necessary, he ought not on that account to pass the

remainder of his time in a state of inactivity; the soldiers under his authority would soon follow his example, and the enemy, informed of his negligence, would regulate their hour of attack accordingly, with every prospect of success.

Not to fatigue the troops too much, they should be divided into four reliefs.

One relief is held in readiness for action, or is employed improving the defences; a second furnishes guards and patrols; the two others repose.

To Guard and Defend an Earthen Work.

196. The first care of an officer in command of a detachment sent to occupy a work, is that of placing his sentries, both in the interior, and externally. A sentry should be placed in the interior at each of the salient angles of the work, and externally to guard each of the avenues by which an enemy might approach, principally on the side next him, but not neglecting to place some sentries to watch the approaches on the other sides; for the enemy might turn the post with a view to take it by surprise.

If in front of the work there be a bridge, a causeway, a defile, or a ford, over or through which the enemy is compelled to pass, and which can neither be destroyed nor occupied—if there be any house, or hollow road, or ravine, in which he might secrete himself, a few intelligent and trustworthy men should be placed to watch those points, and to give timely notice of the enemy's movements.

In general, the sentries are most numerously posted on those sides of the work easiest of access to the enemy. They should always have particular instructions given them as to their conduct in the event of an attack, either on the side they are posted to guard, or on any other point.

The patrols sent out to ascertain whether the sentries are on the alert, or to reconnoitre the enemy, should be taught that they are not sent to fight, but to inspect carefully the hollow ways, hedges, ditches, woods, and houses, in the neighbourhood, and to give information of what they may discover to the officer in charge of the post.

But if a patrol accidentally encounter any small party of the enemy, they should attack them instantly with the bayonet, and drive them as far off as possible.

If the patrol fall in with an ambuscade, they should instantly fire on them, however superior their numbers, in order to awaken the vigilance of any party of their comrades who may be approaching.

These precautions, and others which circumstances will suggest, may be sufficient to prevent the enemy either surprising or reconnoitring a post.

Intelligence as to the enemy's numbers, position, preparations, &c. may often be obtained from the peasantry of the country; but these sources of information are always liable to suspicion; for the enemy may bribe some of the natives to give false intelligence, or may cause persons in his service to

spread rumours of such import as he would wish to be believed.

After having taken the precautions already mentioned against surprise, the commandant of the post should next prepare his measures of defence, and point out to his detachment their respective duties, under the several circumstances to which an attack may give rise. He will instruct them not to approach the parapet, or to fire until the enemy is within 200 yards of the work, the fire of musketry being of little value at a greater distance.

197. The moment the enemy makes his appearance, the commanding officer should order the detachment to stand to their arms, and send a messenger to the general, or other commanding officer of the troops in the neighbourhood. He should then inspect every part of the work, to see that his previous orders have been strictly adhered to, and that every one is at his assigned post.

If the enemy have breached the parapet with his artillery, it should be protected with limbs of trees, chevaux-de-frise, planks with spikes driven through them, crows' feet, or other impediments previously collected in the interior of the work for this purpose.

The reserve should be posted near the centre of the work, ready to give assistance wherever the assailants are on the point of effecting an entrance.

We have supposed the enemy to have attacked all the assailable points at the same moment. If the attack were only partial, then the parts

attacked, would be reinforced by the troops originally posted to defend the other faces.

The defenders should endeavour to distinguish the true from the feigned attacks; for a skilful antagonist always forms several, particularly during the night, and these false or true attacks often change their object, according to the degree of resistance they may happen to meet.

If, after having valiantly defended a post, no aid be expected, and the garrison be reduced to the last extremity, they should endeavour to escape during the night.

The commandant of a post should, however, never forget that this is to be his last resource; and that however unimportant the work may appear, the prolongation of its defence for only a quarter of an hour, may perhaps save an entire division or corps.

*Manner of Guarding, and Defending a Church, a Country-Seat, or a House.**

198. What has been already stated with regard to vigilance, and the posting of sentries, &c. is equally applicable to the defence of churches, farm-houses, or other buildings.

These edifices being secured from surprise, the preparatory arrangements for their defence are to be made.

* Large public buildings and institutions, such as the county goals of this country, are generally admirably calculated for defence; and it is only to be regretted that they are not invariably constructed with flank defence.

The commandant of the post should divide his corps into as many parties as there are floors to be occupied, placing one or two men to defend each window, and overturn any ladders the enemy may plant, to scale the walls.

Two men should be posted at each loop-hole on the ground floor: one man will be sufficient to defend each loop-hole on the upper floors.

After having made as great a resistance as possible on the ground floor, the defenders mount to the first floor, drawing up their ladders after them. They then keep up the heaviest fire possible on the enemy below, through loop-holes made in the floor for this purpose. If the assailants commence collecting combustible materials to burn the house, they should endeavour to wet them. If the enemy try to undermine the walls, burst the doors, or scale the windows, heavy blocks of wet timber, stones, bricks, or other materials, should be thrown on him; taking care not to make too liberal a use of these means of defence during the first efforts of the enemy, and thus to exhaust your supply, before the attack has assumed its most formidable aspect.

In defending a house, it would rarely be advisable to make sorties, because the narrowness of the passages through which the troops would have to file would prevent your shewing the enemy a good front, or making a secure retreat in case of necessity.

Manner of Guarding and Defending an Intrenched Village.

199. After having provided for the security of the village by taking the proper measures to prevent a surprise, the commandant should place a guard in the house or church occupied as an interior intrenchment, and another at the spot where the reserve is to be posted. These different guards should have a ready and secure communication with each other.

If cavalry form part of the force, some small posts should be kept on the outside of the fortified enceinte, their object being to patrol the neighbourhood, especially on the side of the enemy. At night, these posts are to be replaced by small detachments of infantry, who perform the duties already pointed out for the advanced posts.

Each detachment should have with them one or two horsemen, who may speedily communicate to the commandant, information of any discoveries made by the patrols in the execution of their duties.

If the post be traversed by a small river, the points where it enters and leaves the village should be carefully guarded. To keep the detachment on the alert, and in order to ascertain whether every one knows his post, an alarm may occasionally be given. These alarms should not, however, be oft repeated; one or two will be sufficient to shew whether your troops know their duty, and execute it promptly; more is unnecessary; it would only

harass the men, and perhaps make those negligent, who would otherwise have been all activity.

During the attack the cavalry should be kept in readiness in the immediate vicinity of the point attacked; or if several attacks be made, in the market-place, or other favourable position, from which they can proceed to charge the enemy with vigour, wherever he may penetrate the village.

When the enemy has surmounted the obstacles presented to him, such as abatis, pits, &c., the garrison, if sufficiently numerous, should make a sortie on one or both of his flanks. A well-timed offensive movement can seldom fail to throw him into disorder; because he will immediately imagine that he is assaulting a much more powerful garrison than he had previously supposed, otherwise they would not have ventured, by assuming the offensive, to place themselves on an equality with their assailants.

In a military post, sorties should not be made until the moment the enemy is about to scale the parapet, or when he has been thrown into disorder by the fire of the defenders.

If a military post be blockaded by an enemy, a sortie may sometimes be required to attract his attention, while reinforcements of men, ammunition, or provisions, are arriving.

200. Sorties during an assault should always be powerful, and therefore can only be made when an extensive post is occupied in sufficient force, to be defended with the greatest possible vigour. *Those* made by small numbers will seldom or

never produce an effect, equivalent to the certain disadvantage of being immediately beaten back.

The commandant of an extensive post, should never lead a sortie, except for the purpose of opening a passage through the enemy to escape. He should not let his courage get the better of his judgment, nor unnecessarily expose his life, until he feels himself called on to set an example.

The troops intended for a sortie should be placed near the points of issue; they march at a given signal, when the fire from the intrenchment must cease. They are not to halt, or commence firing, but to proceed at once to use the bayonet. Having effected their object, they are immediately to return at a double pace, the reserve being held in readiness to support the retreat if necessary, and the parapets near the barriers being well manned.

If the post be so strongly intrenched as to compel the enemy to cannonade it, a second line of defence may be prepared, so soon as his arrangements indicate on what part of the post he intends to direct his attack.

It is supposed that the streets have already been well barricaded, the walls of the houses loop-holed, &c.; what may be now done is, to barricade the space between the houses and the enceinte, either with an abatis or any other impediments, in order that if the enemy get possession of the part he is about to attack, his lateral movements may be efficiently obstructed.

When the defenders can no longer resist the

attack directed against the general enceinte, they retire to the interior intrenchment, where they will continue to defend themselves in such manner as the means there provided may permit.

On the Attack.

201. The manner of attacking field-works is very different from that employed in the attack of fortresses.

In the attack of field-works the assailants are always more or less exposed to view; in that of fortresses, their approaches are made by excavating trenches, the bottoms of which form the road by which they advance, and the earth excavated being thrown towards the place protects them from its fire.

An officer charged with the attack of a military post should first endeavour to procure—from plans of the country—from a careful reconnoissance, and from spies, a knowledge of the nature of the ground occupied by the post—the various roads by which it may be approached—the description of works thrown up for the defence—the number and description of troops opposed to him—the quantity of ammunition, provisions, &c. with which they are supplied—the manner in which the military duties are performed—the disposition and habits of the commanding officer—the probable succour the post may receive, and how long it must hold out, in order to benefit by that aid.

If the post be only a church or farm-house,

he should, if possible, find out what internal arrangements have been made, how the doors, windows, and different floors, are defended, whether loop-holes have been pierced in the walls, and floors, tambours been made, and ditches excavated, &c.

If the post be an intrenched village, he must endeavour to learn what avenues the enemy has closed, and in what manner it has been done, how the houses skirting the village have been fortified, and what building has been selected for the interior redoubt.

There are three methods of attack, distinguished as attacks by *surprise*, *stratagem*, or *force*.

Attacks by Surprise.

202. To succeed in an attack by surprise, it is desirable to deceive the enemy by making such arrangements as would lead him to imagine that some totally different enterprise was meditated.

The winter is the most favourable season for executing such attacks, or during the time, that dense fogs conceal all distant objects. They are usually commenced about two hours before daylight; and the march of the troops should be so regulated that they may arrive in the neighbourhood at that time.

If the post to be surprised can be readily succoured, the attack should be made early enough to allow of the enterprise being completed, and the retreat commenced, before the dawn of day, if, as is here supposed, the force which can be

brought in aid of the garrison be more numerous than the attacking corps.

An attack must not, however, be commenced before the garrison and inhabitants have retired to rest; consequently not much before midnight.

The strength of the detachment employed in the attack is to be proportioned to that of the garrison, and of the corps whose aid they may probably obtain, the number of defiles or passes it may be necessary to occupy, (in order to secure a retreat,) and of true or false attacks intended to be made.

203. The men who undertake a surprise may be divided into four parties: 1st, the guides and interpreters; 2d, the combatants; 3d, the troops to cover the retreat; 4th, the working party.

Before the care of conducting the different detachments is confided to the guides, it must be ascertained that their knowledge of the environs is sufficiently perfect to enable them to fulfil their obligations, promising them an ample remuneration if they do their duty faithfully, and a certain death if they mislead, or in any other manner attempt to deceive.

Each detachment should be accompanied by at least two guides, that if one be killed or wounded, another may be ready to take his place; they likewise act as a check on each other.

The troops should never be allowed to fire in making an attack by surprise, but must endeavour to surmount every obstacle silently, until they can contend hand to hand with the enemy.

Bags made either of leather or canvass, filled with powder, and a fuze attached, must be provided, for bursting open gates or barriers, and blowing up wooden bridges. The bag of powder is to be suspended to, or propped against the wood-work, in the readiest manner that offers, and a gimlet should be carried with the bag for this purpose.

Strong pincers, heavy hammers, and iron wedges, are also required for breaking open the barriers, knocking off the locks, or drawing the hinges of the gates. Hand-saws or axes are carried for cutting the fraises, palisades, and barriers; shovels and pick-axes to cut away the crest of the counterscarp to render its descent more easy, and to sap the salient angles of the intrenchments; steel spikes to spike the guns; and ladders to scale the stoccades or garden-walls, &c.

After having made provision for the several objects above specified, the commanding officer, when the attack is on a large scale, should divide his detachment into five portions,—one to execute the true attack, a second to make two or three false attacks, a third to oppose the party sent in aid of the post, or to create a diversion by attacking some other part of the enemy's position, a fourth to form a reserve, and the fifth to guard the defiles and cover the retreat. This supposes the projected attack to be made with numerous forces against a formidable adversary, intrenched in an extensive position.

In some cases, however, a body of troops might not be required to cover the retreat. This is only mentioned, therefore, by way of example; for generally the troops to cover the retreat are a body independent of the attacking corps.

It is not possible to say what proportions these several detachments should bear to one another; that destined for the true attack must not, however, be less than one-third of the garrison; those for the false attacks should also be considerable, otherwise they would be unable to take advantage of any unexpected success on their parts.

The corps to oppose the expected succour, and that left to guard the defiles, &c. should be proportioned, the one to the probable number of troops which may be detached in aid of the post, the other to the number and capabilities of defence of the defiles they may have to occupy, and the distance between the assailants, and their point of departure.

The reserve should be the most numerous body, and, if possible, be composed of old soldiers. They ought to be placed in such a position with reference to the true, and false attacks, that they may give assistance to whichever party first penetrates the enemy's intrenchments.

When the officer commanding the principal attack approaches the counterscarp, he should push forward the party who carry the scaling ladders, which party must consist of two divisions: the first lower their ladders into the ditch, descend

the counterscarp, and place the same ladders against the escarp; the second division lower their ladders, and, descending into the ditch, are immediately followed by the remainder of the storming party.

If the men who first ascend are perceived, instead of replying to the *qui vive* they must rush quietly towards the sentries, and endeavour either to secure them without noise, or bayonet them.

If the post be surrounded by a wet ditch, fascines are to be thrown into it of 6 feet in length, to form a bridge: if the bottom of the ditch be soft and muddy it must be covered with hurdles prepared for that purpose. The rear divisions of each attack, who in the first instance remain in silence on the counterscarp, follow the first division as soon as it has entered the place.

A detachment should be posted to guard internally the point by which the intrenchments have been penetrated, otherwise the enemy might get possession of it, and prevent any further assistance being given to those who first entered the work.

The detachment which first gets within the enemy's intrenchments should proceed immediately to assist the nearest attack on their flank.

Another should march towards the point indicated for the introduction of the reserve, and open to them a communication.

As soon as the reserve has been introduced, any further orders which may have been given are executed, and each party should repair immedi-

ately to the appointed place of general rendezvous. The first object to be attended to after getting possession of the post, is to secure the persons of the commanding officer, and of the principal magistrates.

The true attack should be made at a point where the houses are most distant from the intrenchment, where the enceinte is feebly guarded, or where the works are not protected by a ditch: in short, the principal attack must be directed against the weakest point of the enemy's post; while, on the contrary, one of the false attacks should be made against the strongest part of the enceinte, where the enemy have least cause to expect an assault.

Although the detachment sent to oppose the arrival of aid, may not have given any intimation of the enemy's approach, the commanding officer must not on that account neglect to take such measures as the nature of the situation requires, to render the arrival of that aid unavailing.

If it be intended to retain the post, proceed immediately to adopt all those means of defence described in the preceding parts of this treatise. If, on the contrary, it is to be abandoned, destroy the fortifications, fill in the ditches, set fire to the abatis, break down the palisades, fraises, and dams, &c.; which done, commence your retreat.

In the rules above detailed, it has been supposed that every measure has had a fortunate result; but numerous obstacles may be opposed to that success by a vigilant and intelligent opponent;

it is necessary, therefore, to consider well the different unfavourable circumstances which might arise, and to instruct the officers in charge of the several detachments what measures they are to take in the event of a failure in one attack, or success in another.

Attacks by Stratagem.

204. It is unnecessary to say much on the subject of attacks by stratagem, because what has been already stated with respect to attacks by surprise is equally applicable to them: secrecy is their soul, and prudence should be observed in the arrangements made for their execution. An active foresight will generally enable the assailant to avoid unnecessary dangers: give the enemy credit for doing his duty properly, and your measures being taken accordingly, a successful termination to the enterprise may be confidently anticipated.

By obtaining the co-operation of some inhabitants, an officer may frequently succeed in introducing himself into a post: in treating with them, he should never forget however, that he is leagued with rogues, who will not hesitate to sacrifice him, if necessary to their own interest.

Circumstances give rise to stratagems, yet these stratagems have bounds; and although we may be justified in deceiving an enemy by every possible artifice, in laying any snare to entrap him, yet all perfidy is disgraceful, and forbidden by the laws of honour.

Attacks by Open Force.

205. Before an officer undertakes to carry a post by open force, he should acquire all the information respecting it detailed in the preceding articles. Every attack requires that he who directs it should be perfectly well acquainted with the nature of the ground on which he is to manœuvre, and have made a close examination of the situation, and of its strong and weak points; for the first arrangements of the attack are always in a great measure dictated by those of the enemy. The rules given for attacks by surprise are also applicable to those by open force. Both require the formation of several attacks, some true, others feigned. These attacks must all commence at the same moment; and if any of the assailing columns have to make a circuit to get opposite their points of attack, they should be informed exactly at what hour they are to give the assault.

Works of slight profile, or weakly garrisoned, may generally be carried by a sudden assault, which should be made just before day-break. If the attack be commenced during day-light, when the troops are in readiness to march, a few detachments of light infantry may be pushed forward to attract the fire of the post from the point of attack, while at the same time the main body of infantry advance with speed, and charge with vigour.

Every attack should be formidable in point of numbers, that the enemy may have real cause for apprehension from each of them.

The enemy should be kept in cneck during the attack, and be prevented reinforcing the post, or manœuvring on the flanks of the assailing columns.

An assault cannot be too rapidly given. A rapid advance raises the spirits of the assailant, and prevents his regarding the dangers on which he is rushing.

The attacks should be so directed that they may succour each other, and be prepared to repel sorties. A military post may be well defended without artillery, but a strongly intrenched post can seldom be carried by open force if unprovided with cannon.

When the escarps cannot be ascended, and no scaling ladders can be procured, a work may be entered by sapping the salient angles of the escarp, or by enlarging any partial breach. The men who first descend into the ditch, in this case, carry with them pickaxes and shovels, &c.; they immediately attack the salient angle of the escarp or breach, and as soon as they have made a practicable passage, enter the post, followed by the remainder of the detachment. When furnished with artillery, it should be placed so as to obtain a slanting fire on the salient angle: a few howitzer-shells well thrown, with long fuzes, will generally make a practicable breach in an earthen work. The breach made, the troops advance in columns to the assault without firing, descend into the ditch, mount the breach, and enter the place.

A redoubt, though of a good profile, may be assaulted in the following manner:—At the first

blush of dawn a troop of horse-artillery should gallop up, unlimber on the glacis, and commence a rapid fire of case-shot, to drive the defenders from the parapets; a working party carrying fascines, followed by a powerful storming party, advance at the same time with the greatest possible speed; the former fill in the ditch enough to enable the latter to cross it, and enter the work, which if thus assaulted by good troops, will certainly be overpowered.

Attacks by open force should generally combine assault, escalade, and attack by the gorge, or rear faces.

When compelled to breach a work with artillery, a small epaulment may be thrown up, with gabions to protect the guns; or, if the site permit, a terreplein may be excavated for them.

206. The means of giving to an intrenched post the greatest degree of strength of which it may be susceptible, have already been described. It now remains to shew in what manner an officer should conduct the attack of a strongly intrenched position.

An abatis may be destroyed either by artillery, or by fire. To destroy an abatis with artillery, place the guns so as to enfilade it, and use ricochet practice. Howitzers are the description of ordnance best adapted for effecting breaches in earthen works, or destroying fraises, palisading, or abatis, &c.

To burn an abatis, lighted faggots may be thrown on it.

Crows' feet may be swept away during the night with branches of trees, which the men drag after them.

If military pits are to be crossed, the men must march in extended order, and at a slow pace.

Chevaux-de-frise are first to be broken by the fire of artillery, then a few resolute men with axes are sent forward to open a passage through them.

Palisades are to be destroyed in a similar manner. First endeavour to damage them by the fire of artillery, then have them cut, set fire to, or pulled up by main force. Breaches may be made in a palisade by attaching a bag of powder to them, and exploding it, as explained in art. 234.

The best method of destroying fraises is to enfilade them with artillery; gaps will then be made of sufficient magnitude to permit of their demolition being completed with axes; or they may be destroyed with powder in the manner alluded to in the last paragraph.

In the attack of fortified houses, the fire of the loop-holes may be stopped by the introduction of small rockets, or any other artificial fire-work, that will create an abundance of smoke.

The walls of a house may be breached by undermining them, or by artillery placed so as to see them in a slant direction; a very few shot taking effect will then bring them down. If a house is to be carried by escalade, it must be attacked on several points at the same moment. If the upper floors are gained, hand-grenades, pitched

faggots, and lighted torches, &c. should be thrown into it.

Churches are attacked in the same manner as houses; but the walls being much thicker, the attack would probably not succeed, unless they were previously breached with artillery.

If the means pointed out as applicable to an attack by open force are provided, the enemy's intrenchments will generally be carried when the assault is given by good troops; success in this description of attack being as much the reward of valour as of art.

When the enemy's fortifications are of so perfect a nature as to render hopeless any attempt to carry them by open force, the method of attack detailed in the 11th chapter of this treatise must be resorted to. Though the planning, and directing attacks of this description would generally be referred to an experienced officer of engineers, of whose duties in the field this forms an important part, yet all military officers ought to understand the principles on which this kind of attack is founded, the description and use of the several intrenchments, batteries, &c. thrown up; and so much of the detail as will enable them in a case of emergency, to proceed with the work commenced under the direction of the engineer.

CHAPTER X.

MILITARY MINING.

Dimensions of Galleries and Branches.

207. The following dimensions are commonly given to the galleries and branches of mines:—

Description of Gallery or Branch.	Height in the clear.	Breadth in the clear.
Great gallery used for descents into ditches, &c....	6′ 0″ to 6′ 6″	5′ 0″ to 6′ 6″
Common great gallery........	6 0 — 6 6	3 3 — 3 6
Common gallery...............	4 3 — 5 0	3 3 — 3 6
Great branch..................	3 0 — 3 6	2 6 — 2 9
Small branch..................	2 6 — 2 9	2 0 — 2 4

These galleries and branches, when used for permanent purposes, are constructed of masonry. In works of a temporary nature they are formed with frames of wood, the sides and top secured with planks called *sheeting*.

Each frame consists of four pieces, viz. a ground-sill, two stanchions, and a cap-sill. These pieces are connected together at the ends by notches cut in each, Fig. 99, of an inch or an inch and a half in depth. The following table shews the scantling

for gallery frames, supposing the earth to be of a medium consistency, and the wood to be well-seasoned oak :—

Description of Gallery or Branch.	Ground-sill.	Stanchions.	Cap-sill.
Great gallery	6″ × 4½″	6″ × 6″	7″ × 6″
Common great gallery..	5 × 4	5 × 5	6 × 5
Common gallery.........	4½ × 3½	4½ × 4½	5 × 4½
Great branch	3½ × 3	3½ × 3½	4½ × 3½
Small branch	3 × 3	3 × 3	4 × 3

The top sheeting is from 3 feet 6 inches to 4 feet long, from 7 inches to 1 foot wide, and from 1 inch to 1½ inches thick. The side sheeting should be from ¾ of an inch to 1 inch thick.

The frames are connected together by a batten, 2½ to 3 inches wide and 1 inch thick.

Dimensions of Shafts.

208. When a gallery is to be driven at the bottom of a shaft, the width of the shaft in the clear must be equal to that of the gallery from out to out.

If the shaft be sunk merely for the purpose of demolition, it should be made as small as possible. A shaft 3 feet by 2 feet is the smallest in which a miner can conveniently work after sinking 6 feet in depth.

Two kinds of frames are used for shafts, viz. top frames and side frames.

The top frame consists of four pieces, halved

to fit each other, with an overlength of from 1½ to 2 feet, Fig. 100. The side frames also consist of four pieces, the ends halved to fit one another, Fig. 101. Each piece of the shaft-frame has a line or score cut with a saw on all its faces, marking the middle of the piece.

The scantling for the top frames of a shaft should generally be larger than for the side frames, the former being 6 inches, and the latter 4½ inches square.

When the shaft is less than 4 feet 4 inches wide in the clear, the scantling may be reduced.

209. If it were required to drive a gallery from the bottom of a shaft, the distance at which the floor of the gallery is to be placed below the surface of the ground being given, the first thing to be done is to determine the length of the intervals.

An interval of a shaft or gallery is the vertical or horizontal distance between two frames, added to the thickness of one of those frames.

To find the length of the intervals, let us suppose that a common gallery 4 feet 6 inches high in the clear is to be driven from the bottom of a shaft 22 feet deep.

To find the depth of the last interval we then have—

	′	″
Height of the gallery from the top of the ground-sill to the top of the cap-sill	4	11
Thickness of top sheeting	0	1
Free space for the introduction of the top sheeting .	0	2
Thickness of the shaft-frame next above the gallery .	0	4½
Total . . .	5	6½

Subtract 5 feet $6\frac{1}{2}$ inches from the total depth of 22 feet, there remains 16 feet $6\frac{1}{2}$ inches.

There would then be required four intervals of 3 feet 4 inches each, and one of 3 feet $2\frac{1}{2}$ inches, Fig. 102.

In sinking the shaft the frames are connected together by battens, similar to those described in art. 207, their length being equal to that of an interval, added to the thickness of a shaft-frame.

These battens are nailed to the shaft-frames 4 inches from their halvings, on the opposite sides of the shaft, two pieces of the frame being thus suspended by them, with the halvings turned upwards; the other two pieces are fitted on the first, and to these the battens of the next interval are nailed: so that if (Fig. 100) the battens of the first interval were nailed to the pieces 1 and 3, those of the second interval would be nailed to the pieces of the shaft-frame next below 2 and 4.

Having determined the length of the intervals, three pickets are to be driven into the ground 9 or 10 feet apart, one to mark the centre of the shaft, the others to shew with it the direction of the axis or central line of the intended gallery. The top frame of the shaft is then let into the ground, taking care that it is perfectly level, that the semi-diagonals measured from the central picket are all equal, and that the scores of two opposite pieces of the frame are laid exactly in the direction of the axis of the gallery marked by the three pickets previously driven.

The ends of the top frame should be secured

with pickets, driving them at both ends of each piece at the same time. When the ground is irregular a level berth for the top frame must be excavated. In favourable soil it may not be necessary to introduce more than two or three pieces of sheeting on each side of the shaft, after the interval has been excavated, and the first frame of the next interval has been placed. In unfavourable soil, on the contrary, the sheeting must be introduced behind the frames, after excavating a portion only of the interval; in this case a false frame is used to keep the sheeting in its place. The false frame is similar to the side frames, but a little longer in the clear. The manner of using it is sufficiently explained by Fig. 103.

In sinking the shaft care must be taken, that all the scores of the frames lie on each side in a vertical line.

When the shaft is sunk to its proper depth, a central picket is to be driven at the bottom, to mark, with the scores on the shaft-frames, the direction of the axis of the gallery.

In favourable soil the sheeting on that side of the last interval on which the gallery is to be driven, may be dispensed with, and the first frame of the gallery be placed on the outside of the shaft, as represented in Fig. 104.

In unfavourable soil the whole shaft must be lined with sheeting, a frame being introduced in the middle of the last interval, Fig. 105.

The first frame of the gallery is then set up within the shaft, and the stanchions are secured

with battens to the intermediate shaft-frame of the last interval. The sheeting opposite to the cap-sill of the first gallery-frame is then forced down with a crow-bar, until sufficient room is obtained to introduce the top sheeting of the gallery and one or two pieces of the side sheeting. A piece of timber is placed across the shaft under the frame next above the gallery, to take the ends of the top sheeting; and the side sheeting, if necessary, must be counter-supported in a similar manner against the sides of the shaft. When the side sheeting has been introduced as far down as the intermediate shaft-frame, that piece of it which extends across the gallery is lifted off the side ones, between which and the stanchions wedges must be previously driven.

210. The top sheeting of the gallery should always be driven as the excavation is advanced; the rear ends of the sheeting being kept down with wedges introduced between it and the top sheeting of the last interval. The thickness of these wedges should be diminished as the work advances.

When the floor of the gallery is level, the battens to secure the stanchions to each other should be nailed alternately 4 and 8 inches below the cap-sill. In ascending or descending galleries, the battens are nailed 4 inches below the lowest cap-sill, and 4 inches added to the thickness of the slope-block, below the highest cap-sill of each interval: they are thus kept level without trouble.

The slope-block is a cube of wood, the side of

the cube made equal to the intended difference of level between the two frames of an interval.

In unfavourable soil a false frame is introduced in the middle of each interval, to take the ends of the sheeting. The false frame, Fig. 106, is a little shorter and wider than the gallery-frames, the cap-sill is rounded at the top, the stanchions have small tenons at their upper ends, which are let into mortices cut in the cap-sill; these mortices are longer than the tenons, a wedge is therefore introduced to keep the stanchions in their places. When the wedge is drawn out, the frame is easily removed: but this is not to be done until the second frame of the interval is put up, and wedges are introduced between it and the sheeting to facilitate the introduction of the sheeting of the next interval.

211. In a descending gallery, the frames, instead of being placed vertically, should be set up perpendicular to the slope; more head-room is thus obtained, and the work can be executed with greater facility. This is the mode adopted at the practical school at Chatham; but the French miners always place the frames perpendicular to the horizon.

Returns in Galleries.

212. When the axes of two galleries meet at a given point, or a change of direction is made in the axis of a gallery, it is called a *return.*

The interval in which the return is made is called a *landing*, and must always be level.

When the return is to be made at right angles with the original gallery, called the *gallery of departure*, the distance of the frames apart must be so regulated that the front of the first frame of the landing may be at a distance from the point of intersection of the axes of the return and gallery of departure, equal to half the width of the return from out to out; the length of the whole landing in the clear being equal to twice that distance, Fig. 107.

If the return form with the gallery of departure an angle greater than 45°, a tracing of the return, similar to Fig. 108, should be made on a floor, in order to determine the exact dimensions of the oblique frame, and the distances required to be known for setting it up accurately.

When the axis of the return forms an angle of less than 45° with that of the gallery of departure, two returns must be made, the first at right angles, the second oblique, as shewn in Fig. 109. If the return is to be made entirely with square frames, then a small retreat, A, Fig. 110, must be excavated to obtain room for the introduction of the sheeting of the return.

When the gallery of departure is not prolonged beyond the return, the frames must be arranged as in Fig. 111.

In favourable soil, when the angle of the return is not less than 60°, the frames may be placed as in Fig. 112.

To find the Length of the Intervals of a Gallery.

213. The length of the intervals of a gallery should evidently be determined before its execution is commenced; but we have deferred explaining this operation, in order that the preceding details may make it the more intelligible.

The officer in charge should first determine, by means of a tracing on the ground, and by levelling, the different horizontal and vertical lengths required to be known.

Given A B the axis of a gallery, its total length 118 feet, Fig. 113. A shaft is sunk at the point A; at the point C, situated 44 feet from A, there is to be a common gallery at right angles to the gallery of departure; at the point D, 44 feet from C, there is to be an oblique return of a great branch, forming with the gallery of departure an angle of 45°.

The part AC is a common great gallery; the part C D a common gallery; and the part D B a great branch.

The levels of the points A C, D B, referred to the same comparative plane, passing above all of them, are,

		′	″
For the point	A....	34	0
„	C....	29	0
„	D....	33	1
„	B....	35	1

Thus, from A to C there is an ascent of 5 feet; from C to D a descent of 4 feet; from D to B a descent of 2 feet.

Part A C, Fig. 114. From the entire length of this part, 44 feet, subtract

	′	″
Half the width in the clear of the shaft	2	2
The thickness of the lower shaft-frame	0	4½
Half the width of the landing at C	2	0½
The thickness of the last ground-sill of the gallery A C	0	5
.	5	0

There will then remain 39 feet, which gives twelve intervals, each one 3 feet 4 inches in length. In these twelve intervals the gallery has to ascend 5 feet, consequently the side of the slope-block will be 5 inches.

Part C D, Fig. 115.—Having constructed the plan of the oblique return to be executed at D, we find that the last frame of C D is to be distant, say 9 inches, from the point D. Then, from the whole distance C D, 44 feet, subtract

	′	″
The half breadth of the landing C	2	0½
The thickness of the gallery-frame placed beyond the point C	0	5
The distance of the point D from the last frame	0	9
The thickness of the last frame of the gallery C D	0	4½
	3	7

There remains 40 feet 5 inches, which gives thirteen intervals, nine of 3 feet 1 inch, and 4 of 3 feet 2 inches. The side of the slope-block will be 3 inches.

Part D B, Fig. 116.—Measure on the plan of the oblique return the distance of the point D from the rear of the frame placed beyond it, to form the landing. We will suppose that this distance is found to be 4 feet 5 inches; then from the whole length of the part DB, 30 feet, subtract

	′	″
The distance above given	4	5
The thickness of the great branch-frame placed beyond D	0	3½
The thickness of the last frame placed at B . .	0	3½
	5	0

There remains 25 feet, or six intervals of 3 feet 2 inches each, and two of 3 feet, the side of the slope-block being 3 inches.

Branch Galleries à la Hollandaise.

214. These galleries are of the same dimensions as small branches: the frames are made of plank; they are placed touching each other, and serve at the same time both as frames and sheeting.

Each frame consists of four pieces; the stanchions have a tenon at each end, Fig. 117, fitting into notches cut in the cap-sill and ground-sill to receive them.

When the gallery is an ascending or descending one, the ends of the stanchions are cut obliquely, in order that their sides may always be vertical.

Fig. 118 is a plan and section of this description of gallery.

Shafts à la Boule.

215. These shafts are lined with frames made of plank, connected together as shewn in Fig. 119.

In Fig. 120 a section of a shaft *à la Boule* is shewn, which is sufficiently explanatory to render any other description unnecessary.

This kind of shaft can only be used with advantage in favourable soil, on account of the difficulty of introducing the frames sufficiently near each other: they are commonly placed 1 foot apart, as shewn in the figure. Large gabions, 6 feet long, and from 3 feet 6 inches to 4 feet in diameter, are sometimes used for lining shafts near the surface, smaller gabions being introduced as the work is proceeded with.

Of Mine Chambers.

216. The chamber of a mine is a cavity formed in any place to receive a charge of powder, intended to be there exploded.

When the chamber is made near the end of a gallery, the centre of the chamber is placed on a level with the floor of the gallery, or a small return is made to receive the charge. When the charge is not required to be exploded immediately, or the ground is much saturated with moisture, it must be placed in a well-pitched wooden case, or a good cask might be employed, or the wooden case may be covered with tarpaulin, or any other expedient adopted that may be at hand—the best is, to introduce the charge in water-tight tin cases.

In dry ground, and when the charge is to be exploded in a short time, it may be contained in bags.

When the case to contain the powder is not more than 2 feet square, it might be brought into the chamber ready made; if of a greater dimension, it must be put together on the spot, the pieces to form the sides being arranged in a manner similar to the frames of branches *à la Hollandaise.*

An opening is to be left at the edge of the cover, about 4 inches square, for the introduction of the charge, and a similar opening in the interior side in which to insert the hose-trough.

The dimensions of the case to contain any given charge is calculated on the supposition that a cubic foot will contain 58·5626 lbs. of powder; 1000 inches will therefore contain 33·89 lbs.

Let P represent the given number of pounds of powder, and x be the side of the cube sought in inches. Then

$$33{\cdot}89 : 10^3 :: P : x^3$$
$$x = 3{\cdot}09 \sqrt[3]{P}.$$

viz. extract the cube root of the given number of pounds of powder, and multiply it by 3·09, or $3\frac{1}{10}$ nearly, for the side of the cube in inches.

Some miners have imagined, that if a certain vacuum were left about the charge, proportioned to its quantity, its effect would be sensibly increased.

This property of the vacuum is not yet sufficiently proved to allow of its adoption in practice.

To place the Hose-Troughs.

217. The hose-troughs are small wooden tunnels, in which the powder-hose intended to communicate the fire to the charge is placed.

These troughs are made 1½ inches square in the clear. The four pieces of which they are composed are called the sill, sides, and top, or cover: they are all from ¼ to ½ an inch in thickness.

The trough should penetrate the powder-case about 4 inches, and should exactly fit the opening left for it.

It is fastened to the floor of the branch by small pickets, to the tops of which the sill of the trough is nailed. Sometimes pickets are driven against the sides of the trough to prevent its being disturbed.

The different lengths of the trough should be sawn square off at each end, so that they may fit exactly. Each portion of the trough should always be accompanied by its cover, well fitted, but fastened with one peg only, in order that it may easily be removed to introduce the powder-hose.

The trough makes an elbow when it changes its direction. The pieces forming an elbow should be solidly yet simply connected. Figs. 121 and 122 shew the most common forms of elbows.

When several mines are to be fired at the same time, it is necessary to proportion their trains,

that is, so to regulate the hose-troughs that, starting from the same point, the distances from that point to the charges may be all equal. To arrive at this result without long trials, proceed as follows:—

For two charges, Fig. 123, place a trough on the shortest line from the one to the other, mark the centre of it, and let the principal trough join it in that point.

For three charges, Fig. 124, connect, as above, the two which are nearest together. Join the middle point of the first trough to the third charge, and divide into two equal parts the whole length between this third charge and one of the former; then let the principal trough be joined to this last central point.

For four charges, Fig. 125, first connect them, two and two, then join the central points, and proceed as above.

The elbows of a trough impede the communication of the fire, for which an allowance must be made when proportioning the trains, each elbow being valued at 3 inches; thus, if on one side of the principal trough there be one elbow more than on the other, the principal trough should be placed 3 inches nearer to that side, which is done by placing it 1½ inches from the central point towards that side.

Square elbows impede the communication of the fire a little more than oblique ones. Experience has also shewn that two powder-hoses may be placed within 18 inches of one another, if

covered with earth, and produce separate explosions.

Common Mines.

218. The line of least resistance of a mine is a line drawn from the centre of the charge to the point where the charge, when exploded, meets with the least resistance. In common cases, this line is a perpendicular drawn from the centre of the charge to the surface of the ground.

The opening produced by the explosion of a mine is called the crater; the radius of the superior base of the crater is called the radius of the crater; and a line drawn from the centre of the charge to any point of the upper edge of the crater, is called the radius of explosion. Thus A B, Fig. 126, is the line of least resistance, B C the radius of the crater, and A C the radius of explosion.

The distance at which a charge can destroy a gallery in its neighbourhood is called the radius of rupture. This radius varies in length according to the direction in which it is measured. When the radius of rupture is inclined below a horizontal line passing through the charge, it is called the sub-horizontal radius.

Charges which produce a crater of a superior radius equal to the line of least resistance, were for a long time the only ones used by miners, and are still called *common mines.*

The form of the solid of earth raised by the explosion of a common mine cannot be exactly known. It is usual to regard it as a truncated cone,

having for its height the line of least resistance; for the radius of its superior base, the same line; and for the radius of its inferior base, the half of that line. In this case, the volume of the common crater will be $\frac{11}{6} l^3$,* or $1{\cdot}83\ l^3$, where l represents the line of least resistance.

Miners have held different opinions as to the solid removed by the explosion of a common mine. Vauban conceived it to be a perfect cone, whose summit was placed in the centre of the charge, and found for its solidity $1{\cdot}05\ l^3$.

Mesgrigny adopted the truncated cone. Lefebre admits the cone of Vauban, but added $\frac{1}{7}$ to its solidity, which gives $1{\cdot}20\ l^3$.

Vallière imagined it to be a paraboloid, having for its focus the centre of the charge, and found its content $1{\cdot}90\ l^3$. Muller truncated the same paraboloid by a plane passing through its focus perpendicular to the line of least resistance, and found its volume $1{\cdot}84\ l^3$.

These different forms of craters caused miners to assume very unequal charges of powder to remove the same mass of earth.

It has been ascertained by experiment, that in common mines the horizontal radius of rupture is equal to $1\frac{3}{4}$ times the line of least resistance, or $\frac{7}{4}\ l$. In a vertical direction, this radius is of the same length as the radius of explosion, and is consequently represented by $l\sqrt{2}$. For the sub-horizontal directions it is admitted that the extremities of the radii of rupture are situated on the surface

* *Vide* Note II. Appendix.

of an ellipsoid, having for its semi-axes the horizontal and vertical radii above determined. Any gallery situated within the limits of this ellipsoid will probably be destroyed.*

Independent of the rupture, the explosion of a mine produces a subterraneous commotion capable of destroying or deranging some parts of a gallery without consequently interrupting the communication. Nothing positive can be said as to the distance to which this commotion may extend; and it may even be observed, that what has been already stated regarding the radii of rupture, is known but in an uncertain manner, and that fresh experiments are much required to obtain more perfect information.

219. To find the charge of a common mine in ordinary earth. Express in feet the line of least resistance, and take $\frac{1}{9}$ of its cube for the charge in pounds.

This practical rule is founded on the supposition that the charges are in proportion to the volumes of the craters, and that for similar craters, as all those of common mines are, the charges should be in proportion to the cubes of the lines of least resistance.

The charge for a common mine may also be found when it is known what quantity of powder is required to raise a cubic yard, by the following rule:

To find the content of the crater. Take $\frac{11}{6}$ of the cube of the line of least resistance, then mul-

* *Vide* Note III. Appendix.

tiply this quantity reduced to cubic yards by the quantity of powder required to raise 1 yard cube, for the charge required.

On the Charges of Common Mines, Globes of Compression, and Undercharged Mines.

220. It has been stated that to find the charge of a common mine in lbs. $\frac{1}{9}$ of the cube of the line of least resistance in feet is to be taken.

This rule, however, is only approximative, and answers but for one description of earth, namely, No. 3 in the following table.

The true rule is founded on the fact ascertained by experiment, that it requires 1 lb. 10 oz. of powder to raise 1 cubic yard of earth, similar to No. 3 in the table. Let it be required to find the charge for a common mine under a line of least resistance of 10 feet. The content of the crater is $\frac{11}{6}\,10^3 = 1833{\cdot}3$ feet $= 67{\cdot}8$ yards, and $67{\cdot}8 \times 1$ lb. 10 oz., gives 110 lbs. 2 oz. for the charge, which, according to the former rule, would be

$$\frac{10^3}{9} = \frac{1000}{9} = \overset{\text{lbs.}}{111}\ \ \overset{\text{oz.}}{1}$$

To find the charge of a common mine for any other description of earth, rock, or masonry, first find the charge as if it were for No. 3. Then ascertain, by weighing 1 cubic foot of the given substance, to which of the descriptions of earth, rock, or masonry, it belongs, and multiply the charge previously found by the corresponding number in the last column of the table, or find the content of the crater in cubic yards, and multiply

it by the charge in the column of charges corresponding to the description of earth, &c. in which the mine is to be placed.

Number.	Description of Earth, Rock, or Masonry.	Weight in lbs. of one cubic foot.	Charges for a cubic yard. lbs.	oz.	Proportional value of charges.
1	Light sandy earth..................	84	1	13	1·12
2	Hard sand	110	2	0	1·25
3	Fat earth, mixed with sand and gravel, called common earth	116	1	10	1·00
4	Wet sand	117	2	2	1·30
5	Earth mixed with small stones...	118	2	4	1·40
6	Clay mixed with loam	124	2	8	1·55
7	Fat earth mixed with pebbles ...	142	2	12	1·70
8	Rock	142	3	10	2·25
9	New or old moist masonry or brick-work	...	2	2	1·30
10	Inferior brick-work or masonry	...	2	11	1·66
11	Good new brick-work or masonry	...	3	10	2·25
12	Good old ditto......................	...	4	1	2·50
13	Roman ditto, or other equally solid; good old brick-work or masonry in warm climates	..	4	11	2·90

221. To find the charge for a globe of compression, or overcharged mine. If the line of least resistance, and the radius of the crater be given, subtract the former from the latter, multiply the remainder by ·8;* to this product add the given line of least resistance, for the line of

* See Note III. Appendix.

least resistance of a common mine requiring the same charge as the globe of compression. Then say—

$$\text{As } 10^3 : 110 :: l^3 : \text{the charge.}$$

The effects of a globe of compression are determined in the same manner as those of a common mine, observing only—to use the line of least resistance found for determining the charge, or from the charge, as the case may be, instead of the given line of least resistance.

222. When it is required to determine the charge of an undercharged mine, the same rule may be followed; in this case, however, the quantity produced by multiplying the difference between the given line of least resistance, and the radius of the crater, by ·8, is to be subtracted from the line of least resistance, instead of being added to it, as in the former case.

The radius of the crater of an undercharged mine should never be less than $\frac{5}{8}$ of the line of least resistance, otherwise no sensible crater would be produced.

Tamping of Mines.

223. When a mine is lodged at the end of a gallery, the gallery must be filled up or tamped, to a distance equal to twice the length of the line of least resistance of the mine, measured in a right line from the charge to the end of the tamping.

The proportion in which a charge for a mine is to be increased on account of imperfect tamping, or of its entire suppression, must depend on the

size of the gallery or shaft as compared with the quantity of the charge. A very large charge for a globe of compression, at the end of a small gallery, would not probably have its effects perceptibly reduced by omitting the tamping altogether, while with a very small charge, the expansive force of the explosion would find vent in a large gallery, without producing any material effect.

When it is not required to preserve a small gallery, or a mine is to be sprung at the bottom of a shaft, sunk for the purpose of demolition, and for tamping which time cannot be allowed, the charge must be increased to make up for the diminution or total suppression of the tamping, in the following proportions:—

An increase of $\frac{1}{4}$ of the charge is equivalent to a reduction of $\frac{1}{3}$ of the tamping.

An increase of $\frac{1}{2}$ to $\frac{2}{3}$ of the tamping.

It may, therefore, be concluded, that if the charge be doubled, the tamping may be wholly dispensed with.

Manner of Firing Mines.

224. The most common methods of firing mines are by the use of the *monk*, or by the *box-trap*.*

These two methods require the use of a powder-hose, by which is meant a long linen bag, from half an inch to an inch in diameter, filled with powder.

The linen used for making the hose should

* La boîte de Boule. *Fr.*

be of a close texture, and the sewing be executed with care.

Manner of using the Monk.

Stretch the extremity of the hose upon a sheet of paper, and sprinkle some dry fine powder on it; cover this powder over with another sheet of paper, secured at its four corners with dry earth or stones; pass a pyramid of agarick* through a hole in the upper sheet; its base should be plunged into the powder, and the top be on the outside of the paper; set fire to the summit of the pyramid with another piece of agarick, usually made in the same form as the first, and retire.

The piece of agarick used to communicate the fire to the powder is called the monk; it should be about 1½ inches long, and be divided by the sheet of paper in two equal parts.

225. *The box-trap*, Fig. 132, is 18 inches high, and 6 inches wide in the clear. The bottom consists of a piece of plank 18 by 10 inches, and its cover is fixed at one side only with a wooden pin, about which it can be turned.

At 6 inches from the top of the box a horizontal slit is made in three of its sides, serving as a groove to a piece of board, which ought to slide freely in it. In the lower part of the box an opening is left to admit the powder-hose on the side not cut for the slide.

Place the box against the extremity of the

* Amadou.

tamping, and secure it well; tie a string to the slide, and lead it along the stanchions of the gallery on pegs introduced for that purpose; put the end of the hose into the box through the hole left for it, and spread on the top of it some fine dry powder; then put in the slide, and close with earth, or rags of sand-bags, all communication between the lower part of the box and the branch; place a star-match of six or eight points, well lighted, on the slide; close the top partly only, then pull the string, and the star will fire the mine.

The two methods above described have the inconvenience of requiring a powder-hose, which, from its own explosion, poisons the galleries. They have also, and particularly the monk, the defect of not producing the explosion always at the instant desired.

The Rocket (Fig. 133.)

226. This rocket is a common one, terminated with a circular head of wood. To use it, a wooden trough, with a smooth interior, must be placed from the charge to the point where the rocket is to start: tin tubes have been recommended, but are found not to answer. A rocket is then placed in the end of the trough, the quick match with which it is provided is lighted, and the rocket starts with very great velocity, penetrates the charge, and fires it.

When the rocket has to pass elbows, or when it is desired to fire several mines at the same

moment, at each turn of the trough a fresh rocket is placed, with its quick-match secured round a nail: the first rocket arriving at the point where the second is placed, fires it. In order the better to insure the first rocket firing the second, a quantity of powder ($\frac{1}{4}$ ounce) should be strewed about the match of the latter, protected by a triangular slip of deal, nailed to the bottom of the trough; the rocket then passes over the powder, which its rapid motion would otherwise disperse.

A rocket may be made to turn in a circular trough, when the radius of that part is not less than twice the length of the rocket.

In order to prevent the smoke of the charge penetrating the gallery through the trough, one or two small iron traps may be placed in the trough, which, being raised by the rocket, fall again by their own weight, and cut off all communication between the gallery and the charge.

The rocket is 6 inches long, will travel 100 yards at least, and its velocity is so great, that two rockets fired at the same moment, to run very different distances, leave no perceptible interval in the times of their arrival. This property renders it easy to proportion the trains of mines to be fired simultaneously, which with powder-hose requires great nicety.

The common rocket contains $\frac{3}{4}$ of an ounce of a composition formed $\frac{2}{5}$ of fine powder, $\frac{2}{5}$ saltpetre, and $\frac{1}{5}$ of charcoal-dust. These ingredients should be very carefully mixed, otherwise some portions of it might explode. Its diameter is nearly $\frac{3}{4}$ of

an inch, and entire weight about $1\frac{1}{2}$ ounce. They may be made much smaller when required.

Blasts.

227. Blasts are small chambers or holes made in rock or masonry whenever the ordinary method of excavation becomes too tedious. The excavation of blast-holes requires the use of particular tools, called borers, jumpers, scrapers, needles, and tamping bars.

To form the blast-hole, two or three men are required; one holds the borer with both hands, while one or two others strike the head of it with sledge hammers. The first turns the borer in every direction, so that the hole may be circular, and from time to time clears it out with the scraper.

When the hole is not required to exceed 15 inches in depth, the whole may be excavated in the above manner; but if required 20 inches, 2 feet, or more, deep, the jumper is made use of. The miner holds the jumper in both hands, raises it, and lets it fall in the hole, turning it continually: he also clears the hole with the scraper. When the stone is of a very hard description, it is usual to pour water occasionally into the jumper-hole.

To load the hole, fill about one-fourth or one-third of it with powder, according to the nature of the stone. The charge for a depth of 18 inches is from 8 to 12 ounces.

To tamp and prime the blast-hole, the needle

is first introduced, plunging it well into the powder, and placing it on the smoothest side of the hole; then a layer of clay is laid on the powder, and is closely pressed down with the tamping bar.

Other similar layers are then laid, or layers of brick reduced to small bits, the needle being turned repeatedly. It is usual to press down the first layers with a bar of wood, the helve of a tool for instance, and the latter ones with the iron tamping bar. When the hole is thus filled up, a small shell of clay is formed round the needle, which is then withdrawn, the hole left by it is filled with fine powder, and it is fired with a monk or a piece of port-fire.

The use of the needle is often dispensed with, in which case the priming is rolled up in a sheet of brown paper, or it is introduced in straw stalks thrust into one another. This priming is placed in the hole at the same time as the charge, so that it may penetrate well into the latter.* The tamping is then executed as before.

The use of the tamping bar may also be dispensed with, filling the whole with very fine dry sand, without any pressure.

Three miners can bore and charge in a day three holes each, 21 inches deep. If they have

* Bickford's "fuze" has now superseded the use of either needle or port-fire in most mines, and it is perfectly safe. It has been tried at Chatham, and found to answer well. Bickford has also invented a "fuze" for burning under water, or in damp ground, which is well spoken of.

very good tools, they can perform the above work in four hours and a half.

When the blast has been fired, the pieces of stone are removed with the aid of crow-bars, and the proper form is given to the excavation.

The result of many experiments has shewn that in blasting rock a large portion of the powder (nearly half) may be dispensed with, by mixing with the remaining powder fine dry saw-dust of elm or beech. A blast thus prepared will have as great an effect as if pure powder were used; the pieces of rock detached are, however, larger, and to finish dividing them, a frequent use of the sledge hammer is required.*

Demolitions.

228. The charges of mines intended to overturn masonry, are calculated as if they were to be exploded in a common soil, making use afterwards of the proportions shewn in the table for the different kinds of masonry to be destroyed.

To Breach a Wall.

First ascertain as nearly as possible the thickness of the wall, and then proceed thus:—

First case.—When the wall is from 2 to 3 feet thick, place one or two barrels of powder against the lower part of it, and fire them.

Second case.—When the wall is from 5 to $6\frac{1}{2}$ feet thick, place one or two charges under its foundations plumb with the centre of the wall.

* See a Memoir of M. Leblanc in No. VII. of the Mémorial de l'Off. du Génie.

Third case.—When the wall is from 9 to 12 feet thick, open at the foot of it, or about 1 foot above the water-level, a branch gallery, which must be driven to the centre of the wall; then make two perpendicular returns to this branch, and place the powder in their extremities, Fig. 134.

To Breach a Wall with a Terrace.

Open at the foot of the wall, or 1 foot above the level of the water, a branch perpendicular to the direction of the revetment; drive through the wall to the earth, then make to the right and left two other branches, following the back of the wall, and equal to its thickness in length; place the charges at the end of these branches, so that the centre of the charge may be flush with the back of the wall.

Demolition of Revetments.

229. When the revetment is without counterforts, or the counterforts are not more than 3 feet thick, several branches are driven perpendicular to the direction of the revetment, at equal distances apart. The charges used should produce craters that would cross each other a little.

When the wall has counterforts of the common dimensions, the charges are placed, as far as practicable, in the centre of them, at their junction with the revetment, Fig. 135.

When but little time is allowed, instead of making one attack for a pair of charges, an attack is made for each, and they are placed at three-

fourths of the thickness of the wall, and so regulated that their craters may slightly cross one another, Fig. 136.

When galleries cannot be driven at the proper level for the charge, as in the demolition of wharfs, &c. shafts are sunk behind the revetment, or at a short distance in the rear of it, Fig. 137, and branches are then driven to the positions for the charges; or, which is still better, because it is a more speedy operation, a shaft may be sunk for each charge.

The depth of the shafts must be sufficient to admit of a proper length of tamping.

If at the same time with the wall a mass of earth in rear of it is to be destroyed, prolong the branches in the interior of the earth sufficiently to allow of the mines at the back of the wall exploding before those placed at their extremities, Fig. 138.

When there is a gallery, Fig. 139, at the back of the revetment, the charges should be placed in this gallery, excavating chambers for them in the revetment at distances apart equal to twice their line of least resistance, viz. at two lined intervals.

All the gallery occupied by the charges is then tamped; at each end the length of the tamping should be equal to twice the line of least resistance of the extreme charges.

The following method is employed also with success. Regarding as the line of least resistance the distance from the gallery to the exterior surface of the wall, imagine a row of common mines

placed at two lined intervals throughout the length, calculate the sum of their charges, to which add one-half for a great gallery; place the whole charge in several heaps, with strong trains leading from one to another. Then tamp strongly and carefully the ends of the gallery, leaving the space intended to be demolished void. When the gallery is more than 2 yards wide and high, or if it have many issues difficult to tamp, the charge of powder must be proportionably augmented.

Demolition of a Tower.

230. If the interior diameter of the tower be 6 yards or more, Fig. 140, drive galleries into the wall from the interior of the tower, and place charges so as to be a little nearer to the interior than to the exterior surface of the wall. When the tower is connected with walls, charges must be placed at their points of junction.

When the tower is but 4 or 5 yards in diameter, Fig. 141, sink a shaft to about the level of the bottom of the foundations, and place a charge there corresponding to the line of least resistance measured from the centre of the charge to the foot of the wall outside.

Cover the floor of the tower with two rows of small beams; then lay two beams crossing, and halved into one another, and propped against the masonry of the arch.

When a shaft cannot be sunk on account of water, and when the tower has loop-holes which prevent charges being placed in the walls, lay the

charge on the floor of the tower enclosed in a strongly constructed case, propped on all sides against the masonry.

When the tower is square, and has several floors or stages, the charges may be placed at the four corners of the ground-story, tamping the first floor.

Demolition of a Powder-Magazine.

231. Place charges in the piers and gable ends, so that their craters may slightly cross each other.

When time presses, a charge is laid on the floor of the magazine, the doors are barricaded, and it is fired with a hose led outside.

To determine the quantity of powder required for the heap, calculate the number of common mines required to overturn a revetment of the same length and thickness as the walls of the magazine, including the piers; add one half to the sum of the charges thus found, and place the whole in one heap in the centre of the magazine.

The above method is only applicable to magazines of not more than 150 square yards surface. If of greater capacity, the quantity first found should be increased $\frac{1}{10}$ for every 15 square yards of additional surface, and be placed in two or more heaps connected with powder-hose, to fire them simultaneously.

Demolition of Bridges.

232. To destroy a bridge the piers of which are from 4 feet 3 inches to 5 feet 2 inches thick, place in one of the piers two charges of 130 to

160 lbs. each, Fig. 142, and secure a plank to the bridge on which to place the powder-hose.

If the pier be from $6\frac{1}{2}$ to 10 feet thick, drive in the middle of it, parallel to its side, two small branches, at the ends of which place charges of from 200 to 230 lbs. each, Fig. 143.

When there is not time to place charges in the interior of the piers, cut a trench over the key of the arch 18 inches deep, in which place 400 to 530 lbs. of powder.

This quantity of powder has broken semi-circular arches of 26 feet span, and $4\frac{1}{4}$ feet thickness at the crown.

A trench in the form of a cross, Fig. 143, may be excavated over the middle of the arch, each branch 10 feet long, and carried down to the extrados. Place in each branch 200 lbs. of powder for an arch $3\frac{1}{4}$ feet thick, and cover the charges with timber, earth, &c.

An arch may also be blown up by suspending an open trough under it with cords, and placing in it charges of powder similar to those already stated for trenches cut on the surface.

When the saving of powder is of consequence, sink a shaft down to one of the haunches, Fig. 144, and place the powder in one mass, unless the bridge be very wide: an arch of 18 inches, or 2 feet thickness of a bridge 20 feet wide, may thus be destroyed with 45 lbs. of powder, if a loading can be applied over the charge giving an equal resistance to the arch.

If the bridge be more than 20 feet wide, two

shafts must be sunk, and charged as before described. When the side walls of the bridge above the piers are slightly built, and the loading of the arch is of loose rubbish, a small gallery should be driven about 5 or 6 feet from the arch stones, to the centre of the bridge, as at A, Fig. 144; a return is then made towards the arch, and the charge is placed in contact with the extrados. Bridges of timber may be blown up by suspending barrels of powder under different bays.

Demolition of a House.

233. Begin by undermining the windows and doors, and cutting away the piers between them, so as to leave the building supported by a few piers only, nearly square. Place then in each of these piers a charge of from 13 to 16 lbs. of powder, tamping well with wood. Proportion the trains to the different charges, so that they may be simultaneously exploded.

234. To destroy palisades, or gates, doors, &c. the best method is to suspend a leathern bag filled with powder, either with a forked stick, strong gimlet, or stout copper nail, against the gate or palisade. The bag should have about an inch of port-fire firmly secured in one side of it, to communicate the fire to the charge. To throw down a strong palisade, from 30 to 50 lbs. of powder should be used. To burst open a town-gate, 60 to 70 lbs. of powder will be required.

Of Fougasses.

235. *Of Common Fougasses.*—Mines are so called when placed at the bottom of small shafts from 9 to 12 feet deep. The powder is lodged in one of the sides of the shaft, and it is fired from a secure spot by means of a powder-hose brought up one side of the shaft, and carried in a trough parallel to the ground 5 or 6 feet below the surface. When there is no occasion to fear shells, it will be sufficient to keep the trough 2 or 2½ feet under the ground. The powder-case and trough should be well pitched, the shaft tamped in the strongest manner, and the earth round about the shaft be dug over, that nothing may indicate to the enemy the position of the fougass.

Of Shell Fougasses.

236. Shells may be buried singly, or in small heaps, and be made to burst either under the ground, or on its surface.

If they are to burst under the earth, they must be sufficiently charged to produce a crater, through which the pieces are projected.

If they are to burst on the surface, the requisite quantity of powder to produce a crater and throw out the shells must be lodged under them, while these latter need only have a sufficient charge to burst them.

In all cases a box is used, Fig. 145, divided into two parts by a partition. The shells are placed in the upper part, their fuzes project

through the partition, and extend from $\frac{1}{2}$ to 1 inch below it.

In the lower part the hose only is placed when the shells are intended to produce their own crater, but powder sufficient to produce the crater is introduced when they are intended to burst on the surface of the ground.

Description of shell.	Full charge of the shell.		Depth at which the full charge produces a crater.	
	lbs.	oz.	′	″
Calibre, 5½	1	0	2	0
„ 8	2	9	2	10
„ 10	5	0	3	6
„ 13	11	0	4	7

Common and shell fougasses produce an effect only near to their craters, consequently they should be exploded at the moment the enemy is above them.

Of Stone Fougasses.

237. Stone fougasses offer the advantage over those already described, of extending their effects to a greater distance; and as they can be easily and speedily executed, they are applicable in field fortification to the defence of ditches and of salient angles; and in permanent fortifications, to the defence of flèches, and other advanced works, and particularly to the defence of breaches.

The most simple method of forming a stone fougass is to excavate an inclined plane, as repre-

sented in Fig. 146, of from 5 to 6 feet deep. At the bottom a box is to be placed, containing 55 lbs. of powder; from this box a powder-hose is led to the point at which it is intended to fire the fougass, or it may be fired by a rocket, art. 226.

A strong shield of wood is placed in front of the charge perpendicular to the axis of the fougass; 3 or 4 cubic yards of pebbles, or an equal weight of other materials, are then filled in against the shield; the earth above the pebbles is to be retained by a revetment of sod-work, and well rammed. A sufficient body of earth must be heaped above the charge to insure its effect taking place in the direction required. A fougass of this kind may be prepared beforehand, and loaded from the rear through a wooden trough introduced for that purpose, which is then tamped with sand-bags filled with earth, each sand-bag being rammed down with a balk.

Twelve men can make a stone fougass 6 feet deep in three hours; which, being charged as before described, will, when exploded, disperse the materials over a space 60 yards in length and 70 yards in width.

CHAPTER XI.

ON THE ATTACK OF FORTRESSES.

238. The first operation of a besieging army is to invest the fortress intended to be attacked. The number and description of troops required for this service must depend upon the strength of the opposing garrison, and the nature of the surrounding ground. If the fortress be situated in a level open country, then the greater part of the investing corps should be composed of cavalry; if in a broken or mountainous tract, then bodies of light infantry are preferable; but whatever the site of the fortress may be, the investing corps should generally contain three or four regiments of light dragoons, with a proportion of field-artillery.

The march of this corps should be so regulated that every avenue to the place may be occupied at the same time. During the day the troops are to be kept out of the range of the enemy's guns, but towards the evening strong parties should gradually be pushed forward, to shut in the garrison as closely as possible. The objects of this first operation, which is called the *Investment*, are to secure all the cattle and forage in the vicinity; to prevent any person escaping from the fortress, or any succours, either of troops, provisions, or ammunition, being thrown into it; and to support

the reconnoissance made by the engineers, who, during the first period of the investment, are employed taking notes of the description of the different fronts, and correcting their plan of the fortress, or making one.

This plan should be on a sufficiently large scale to shew clearly the nature of the ground within 3000 yards of the most advanced works of the place, viz. the course of rivers or streams, ravines, and roads; the extent of inundations, marshes, and woods; and, in short, every thing which might tend to the advantage of the attack, or the contrary. The reconnoissance should be made on every front, in order to keep the enemy in ignorance as to the front or fronts intended to be attacked.

Although in all ordinary cases, as explained in art. 38, lines of contravallation may be dispensed with, yet if the garrison of the place attacked be numerous and well organised, it may be advisable to construct forts or redoubts to command the approaches to the camps, and the flanks of the attack.

239. During the period of the investment the engineers not only correct their plan of the place, from their own observations, but they should also endeavour to discover on what fronts working parties have recently been employed; whether any galleries have been driven under the glacis or elsewhere; in what parts the principal magazines, barracks, and stores are situated; the positions of

the principal squares, and places of exercise for the troops; what number of regiments there are in the garrison; whether they were often manœuvred in the outskirts of the town; what number of cavalry are in the fortress, &c. &c. They then mark accurately with pickets on the ground the prolongations of all the faces of the most salient works, and also of their capitals; the former prolongations should be those of the crests of the parapets, and must be determined with the utmost accuracy; for as the first batteries thrown up are placed on the prolongation of these lines, it follows that they must of necessity be included within the limits of the first parallel, Fig. 163. The positions of the several pickets marking these prolongations should be accurately laid down on the plan: the best times for observing the prolongations of the faces of a work are at the rising and setting of the sun.

240. The alignement of the capitals is required, because it is across these lines that the besieger makes his approaches towards the place; and he does so for the following reasons:—

1st. That it is the shortest road towards the salient angles, where he must of necessity first arrive, those being the points to which he is nearest.

2dly. That he is there less exposed to the enemy's fire, since he cannot be seen by the work nearest to him, and on which he is approaching; and,

3dly. That his approaches being kept near the capitals, they do not mask the fire of his own enfilading batteries.

The prolongation of the capitals need not, however, be so strictly ascertained as those of the crests of the parapets, because it is not of any consequence whether the approaches extend equally to the right and left of them.

Besides the operations already detailed, during the period of the investment working parties are employed in the neighbouring woods, making gabions, fascines, and blind frames, preparing platforms, timber for magazines, and, if necessary, clearing roads for the transport of the battering train, to the great park of artillery.

241. These preliminary arrangements being made, let us examine what is the object of the assailant, and how he may best proceed to effect it. His object is to possess himself of a fortress which impedes his progress, or cramps his operations; and he having eight or ten times as many troops as are supposed to be shut up in the fortress, it follows that the greater number will overpower the less, so soon as they are brought to contend hand to hand.

But the field of battle of the garrison is so organised as to prevent this collision, being surrounded with obstacles which the besieger must overturn, before he can reap the advantage of his numerical superiority.

To reduce as much as possible the necessary sacrifices of a besieger, he is compelled to make

his attack in a systematic manner, requiring more or less time in proportion to the strength of the place attacked, and the valour of its garrison.

The means of attack resorted to since the invention of artillery, consist—

1st. In choosing one or more fronts to attack.

2dly. In destroying the fire of those fronts.

3dly. In making roads by which the assailant may advance unseen to the foot of the ramparts; and,

4thly. In opening those ramparts, forming practicable breaches therein.

When these works are executed in such a manner as to prevent the besieged obstructing the passage of his foe, from the camp to the foot of the breach, the adversaries are then placed so nearly on an equality, that the small garrison must eventually be overpowered by the more numerous troops of the besieger.

The most speedy mode in which any number of men can make for themselves a road, in which they would be concealed from the view of an enemy, is—first to trace the road, so that, if produced, its prolongations would pass clear of the most salient points occupied by him within the range of artillery—and then to dig a trench in that direction, throwing the earth excavated towards the enemy, and making the bottom of that trench of sufficient width to serve as the road required.

242. The project of attack being determined on, the fire of the fronts attacked is to be destroyed.

Now it has been ascertained by experiment, that at 400 yards' distance, two-thirds of the shot fired from heavy ordnance will take effect; at 600 yards, two-fifths to three-fifths; at 800 yards, not more than two-fifths: whence we may assume, that the first batteries thrown up in a siege ought not to be much more than 600 yards from the works intended to be enfiladed by them, because at a greater distance three-fifths of the ammunition would be uselessly expended.

The best offensive position that the besieger can take up, is to open a continuous intrenchment as near the place as possible, and parallel to the general contour of the works, whence it is called the *first parallel, or place of arms* (Fig. 163), its use being to serve as a communication between the several batteries first thrown up, and also as a place of arms, in which to post the guard of the trenches, or troops supporting the attack, who, during the night on which this work is commenced, take post about 100 yards in front of the parallel. The extremities or wings of this parallel are sometimes strengthened with redoubts, and, in general, epaulments to cover cavalry are thrown up a little in rear of those wings or redoubts.

It is always desirable to trace the first parallel within less than 600 yards of the place, if its defective situation, insufficient or inexpert garrison, or other favourable circumstances, will permit.

To communicate between the first parallel and the camp, zig-zag roads (Fig. 163) are formed crossing the capitals, and so directed that their

prolongations may pass in front of the most salient works of the enemy situated within the range of heavy artillery.

243. The opening of the first parallel, and the zig-zag communications in rear of it, is called the *opening of the trenches*, and this work is completed in the first period of twenty-four hours.

Under the protection of the first parallel, batteries of cannon, howitzers, and mortars, are constructed to destroy the fire of the works attacked; zig-zag roads are excavated in front of the parallel, crossing the capitals as before, and defiladed from the enemy's works; under cover of their parapets, the assailant advances to within about 300 yards of the salient angles of the fortress, where he forms a second parallel (Fig. 163), or place of arms. This is necessary, because he must always have a place of arms nearer the head of his attack, than those possessed by the enemy, in order to give it support.

In front of, or in the second parallel, batteries are again constructed, to enfilade the faces and flanks of the works attacked, or to counter-batter any collateral works of the enemy, the prolongations of which either have not been, or could not be, embraced by the first parallel, though their fire must be subdued.

244. From the second parallel the assailant again advances in zig-zags towards the place; and when arrived at about 150 yards from the enemy's covered way, he forms other places of arms, called *demi-parallels*, their object being to support the

head of the attack, and to procure a position for the more advantageous use of small mortars, which, at this period of the siege, are required to drive the infantry out of the salient angles of the covered way.

The besieger then continues to advance, as before, until he arrives at the foot of the glacis, where he forms a third parallel.

245. The next operation of the besieger is to *crown the covered way*, and this may be done either by assault, or by the continuation of the approaches. The former method has been frequently tried, and has often failed.

When it is intended to crown the covered way by assault, the interior of the third parallel is formed in steps Fig. 155, on both sides of the capital of the works to be assaulted, in order that the storming and working parties may shew a large front. The storming party rush boldly into the covered way, and force the enemy into the intrenchments of the places of arms, occupying the traverses of the covered way, behind which they procure such shelter as their dilapidated state may afford. The working party in the meanwhile, trace with gabions as speedily as possible, the form of the proposed trenches, and lose no time in covering themselves.

These trenches are, in the first instance, not traced further than to the second traverse of the covered way, the crowning of which to that distance, will be sufficient to ensure its possession to the assailant.

246. If systematic approaches are resorted to, then the besieger debouches from the third parallel, forming what are called *the circular portions;* these are traced across the capitals, making the segment of a circle, its chord 60 or 80 yards long, and height 20 or 30 yards. On the reverse of this circular portion are collected the materials for the further progress of the attack, which consists of a double sap, Figs. 158 and 159, directed along the capital. Having arrived within 30 or 40 yards of the salient angle of the covered way, the besieger turns to the right and left, forming trenches parallel to its crests, and carried to about 15 or 20 yards beyond their prolongations; a return is then made to the trench, and the whole of the end of each is converted into a *trench cavalier* Fig. 160 ; the object of which being to obtain a superiority of position for the infantry, it follows that the crest of the trench cavalier must be made to command that of the covered way, the defenders of which are then compelled to retire behind the traverses of the place of arms.

The besieger again advances on the capital, and when at 6 or 7 yards from the salient angle of the covered way, the trench is carried parallel to its branches, so as to leave 15 or 18 feet of earth between it and the interior slope of the glacis. As soon as these works are sufficiently carried forward, the lodgement is converted into batteries, to breach the faces of the bastion through the ditches of the ravelin, to breach the salient angle of the ravelin, and to counterbatter the flanks of

the collateral bastions; these latter batteries being constructed on the crest of the glacis of the body of the place.

While these several breaching and counter-batteries are completing, and when completed employed battering the revetments, a descent is made into the ditch of the ravelin Fig. 164. A breach being made, the assailant saps from the bottom of the descent, across the ditch of the ravelin, and makes a lodgement on the top of the breach; this secures to him the possession of the ravelin, along the ditch of which he pushes a zig-zag sap, towards the breach in the face of the bastion, which, if there be any formidable intrenchment in the interior, must be crowned. This lodgement is then extended along the terre-plein of the bastion unoccupied by the intrenchments of the besieged. Portions of it are converted into batteries, to destroy the enemy's intrenchments; and this done, the garrison can only continue to resist by occupying the neighbouring houses, which they must have previously fortified in the manner already described. When the houses are built in a solid manner, and are favourably situated for defence, the besiegers may yet find much to do, if the exertions of a valorous garrison are directed by the skill of well-instructed officers.

247. Having given this general description of the mode of attack adopted against fortresses, it remains to be shewn in what manner the various works are to be executed. It is not intended

to give any very minute details on this subject, but only such as are necessary to render the description before mentioned, more easily understood.

The first parallel, and the communications between it and the depôts or camps, are traced on the ground with a cord, having pieces of white tape fastened to it, dividing it into portions of 6 feet each. The working party, each man carrying a pickaxe and shovel, advance by the most convenient routes the ground presents, in Indian file. Arriving at the position of the parallel, they front form, and extend, each man occupying one of the spaces of 6 feet—their task, for eight hours' work, being to excavate that length of trench, making it 5 feet wide, and 3 feet deep. The second relief widens the trench 5 feet, and the third completes its form, as shewn in Figs. 151 and 152; some portions of the parallel being made with steps Fig. 153, to facilitate the egress of the guard of the trenches, if required to repel sorties. There should be four reliefs for the working party, each relief working eight hours, or until their task is completed. Sometimes a light fascine is used to mark the tasks, in which case the fascines are placed touching each other, in front of the tracing line.

If the working party be armed, the officer arranging them takes each man's musket as he files up, and places it parallel to, and about 8 feet in rear of, the parallel; each man then has to excavate the trench in front of his own musket. The

arrangements of the working party for throwing up the enfilading batteries, would be similar to those already detailed in art. 68. Sometimes it is necessary, on account of the thinness of the layer of earth, or the small depth to which a ditch can be sunk without getting water, or from its being necessary to procure cover in the shortest possible time, that men should be employed both in front and rear of the battery throwing up earth to form a parapet.

It has already occurred (and no doubt will again), that the parapet or epaulment has been formed entirely of earth in sand-bags; one of the most extensive parapets ever thrown up in one night, was made in the manner just described.*

The zig-zag communications between the first and second parallels are traced and executed in the same manner as the first parallel; but when the head of the attack is within the range of grape-shot, it is necessary to procure cover for the workmen with as little delay as possible; and gabions are therefore used to revet the interior of the second parallel. The gabions are placed by one working party, and the trench in rear of them is dug by another, brought to the spot after the tracing is completed; or the same working party place the gabions and excavate the trench, in which case each man carries two gabions, a pick-axe, and a shovel, having to excavate the parallel in rear of two gabions. During the night large

* At the siege of Gibraltar.

portions of the trenches in front of the second parallel may be executed in the manner just described; but in the day-time no advance can be made above ground, until the besiegers have silenced the artillery of the fortress; the sapper is then called on to exercise his peculiar art, an art by which he is enabled to continue advancing in the face of the enemy's musketry.

In Fig. 157 is represented a plan and section of the single sap, used in the formations of zig-zags, parallels, and crowning of the covered way. The head of the sap is covered by a sap-roller, viz. a large stuffed gabion, and the side is protected by a cast-iron or wooden shield or mantelet. The first, second, and third sappers work on their knees. The first excavates a trench 18 inches wide and deep, leaving a berm of 1 foot; the second widens the work of the first 20 inches; the third deepens the work of the second 18 inches; and the fourth widens the whole trench 10 inches. A sap-faggot Fig. 149, is placed between each pair of gabions, to catch any shot which might otherwise pass between them. The sap-faggot has a strong stake in the middle, which being driven into the ground, secures it in its berth. Instead of a sap-faggot, two sand-bags filled with earth, placed on end one above the other, are often used to close the space between the gabions.

When it is necessary to form batteries within musket-range of the works occupied by the enemy, portions of the parallels may be converted into

batteries, which are then called sunken batteries Fig. 162. In this case, a communication must be made in rear, that the service of the battery may not be disturbed by the passage of bodies of men through it.

The zig-zags may often require a greater relief than the parallels, because they are obliquely traced with regard to the general contour of the fortress, and consequently their parapets have to cover a greater width of trench, than those of the parallels. This additional relief is given by placing two fascines on the gabions, side by side, and one on them, as shewn in Fig. 156 : the fascines used are 6 feet long and 7 inches in diameter.

When the angle formed by the adjacent zig-zags becomes very small, or rather when 100 yards of the zig-zag does not carry the approaches so much as 32 yards in advance (those being the proportionate rates at which the single and double sap can be executed), then they should be direct, and consist of a double sap, as represented in Figs. 158 and 159. It may sometimes be necessary to cover the direct saps in the manner shewn in Fig. 161.

Since the attack cannot be advanced during daylight, while the artillery of the fortress remain uninjured, it must evidently be one of the first objects of the besieger to destroy that artillery; but when the guns are placed under the protection of good traverses, and in blinded batteries, this will be a very tedious operation, which the engineer may however, if well supported, be

able to effect. The infantry of the besieger once placed within an easy musket-range of the enemy's guns, they will soon be silenced; the heads of the attack should therefore always be manned with good marksmen, as soon as a favourable position for them is obtained. The better to effect this object, portions of parallels, called demi-parallels, are formed, in which coehorn and royal mortars are also placed to enfilade the branches of the covered way, and destroy the enemy's intrenchments in the places of arms.

248. To estimate the strength of working parties, the number of tools, and the quantity of materials required for each night's work, exclusive of reserves, the following assumptions may be made.

In the execution of the first parallel and its communications, together with the zig-zags between the first and second parallels, one man, with a pickaxe and shovel, excavates 6 feet lineal of the trench.

To throw up an elevated battery, if revetted with fascines, the following working party, materials, and tools, are required:

For each Gun, Mortar, Traverse, or Epaulment.

2 Sappers, with 6 assistants to revet the work.	1 Bundle of 50 pickets to 6 fascines.
12 Infantry to excavate the ditch, & form the parapet.	3 Mauls.
	3 Rammers.
9 Pickaxes.	1 Saw to every 2 guns, &c.
15 Shovels.	1 Hatchet per gun, &c.
14 Fascines, 18 feet long each.	1 Bill-hook.

1 Field-service level.
1 Six-feet rod.
1 Bundle of matches, to every 3 guns, &c.
1 Lantern, ditto.
1 lb. of candles, ditto.
1 Bundle of gads to each gun, &c.
1 Tape of 50 feet in length per battery.

249. To throw up an elevated battery, if revetted with gabions:

For each Gun, Mortar, Traverse, or Epaulment.

2 Sappers.
12 Infantry.
6 Pickaxes.
12 Shovels.
22 Gabions for each gun or epaulment.
15 Gabions for each mortar.
40 Gabions for each traverse.
2 Fascines for each gun, &c.
50 Sand-bags for each traverse.
3 Rammers for each gun, &c.
1 Maul, ditto.
1 Hatchet, ditto.
1 Field-service level, ditto.
1 Six-feet rod, ditto.
1 Bundle of matches, to 3 guns, &c.
1 Lantern, ditto.
1 lb. of candles, ditto.

250. To lay a Platform.

3 Sappers.
3 Infantry.
3 Pickaxes.
3 Shovels.
6 Rack-lashings and sticks.

251. For each gun or howitzer platform:

1 Stout fascine 9 feet long, to serve as a hurter.
20 Strong pickets, to secure the sleepers of the platform in their berths.
1 Mallet for driving the pickets.

The sleepers of the mortar-platform must be similarly secured.

If the site of the platform required excavation or filling up, that work is supposed to have been done by the last relief employed on the battery.

252. For the formation of each powder magazine:

2 Sappers.	1 Set of magazine timbers.*
10 Infantry.	1 Large tarpaulin.
10 Pickaxes.	4 Common gallery frames.*
10 Shovels.	50 Pieces of sheeting.*
4 Rammers.	8 Fascine.

253. For the execution of a flying sap, traced with gabions, one infantry soldier to two gabions, with a pickaxe and shovel.

The task for each man may be to make the trench 6 feet wide, and 3 feet deep behind the two gabions, leaving a berm of $1\frac{1}{2}$ feet.

254. For the execution of single, and double saps:—three reliefs of four sappers to each single sap, viz. twelve sappers, who should be relieved every four hours at least; two sand-bags or one sap-faggot for each gabion; one large sap-roller for each single sap; two large, and one small sap-roller, for each double sap.

The sappers' tools are estimated for according to the number of demi-brigades employed.

* The powder-magazines may be made with gabions and fascines, with flooring-joist, or stout limbs of trees, or boards on edge, to form the ceiling, placed touching one another, covered with fascines and earth. These materials can generally be procured on the spot, and save the transport of magazine timbers, &c.

A brigade consists of eight sappers.

255. To calculate the number of men, &c., required to supply the quantity of fascines and gabions demanded, see art. 74, 75, and 81 ; to which it is only necessary to add, that for the six-feet fascine two bill-hooks, one saw, one fascine-choaker, and three fascine-horses, are required; and that thirteen men can make five gabions in three quarters of an hour, their tools being one saw, two bill-hooks, five mallets, and five directing circles.

Four sappers can make a large sap-roller in six hours.

It is to be understood that the men employed making fascines and gabions must have been previously taught, otherwise they would be a much longer time making any given number, than has been above assumed.

CHAPTER XII.

MILITARY RECONNOISSANCE.

256. When no accurate map of the country which is the seat of war can be obtained, or when the map possessed (as is generally the case) is on too small a scale to shew its military features in the requisite detail, the general commanding, or the chief of his staff, sends out individuals properly qualified to examine and make representations of such portions of it as he intends to occupy, or may be compelled to move his troops upon; and the delineation of these features so obtained is called a Military Sketch, which differs from an ordinary map on a large scale in having only such pretensions to trigonometrical accuracy as the time allowed, and the circumstances under which it may be necessary to make it, leave in the power of the individuals employed to bestow.

Sketches are made either,

1st, Simply for the march of troops from one station to another, without reference to an enemy.

2dly, When the ground to be moved on is occupied by an enemy whom it is intended to force.

3dly, When retreating before an enemy.

4thly, When time and security permit a more accurate delineation of the ground.

It is presumed that the beginner in field-sketching has already learned to copy plans, and can use his pencil and pen freely in describing ground.* He should commence his field-work in a road, near the banks of a stream, outline of a wood, or any other remarkable feature. Taking a road, for instance, he should start from a conspicuous point, and mark it in his paper. From this point he should trace faint lines in the direction of any objects of consequence he may see, such as a house, steeple, tower, &c., and on the line so traced put the distance in paces that he conceives it to be from him. Then looking along the line of road he has to sketch, as far as his eye will reach with precision, and selecting a convenient object to be another point on the paper, he should estimate the distance it may be from him, and having put it down according to his scale, which scale should be notched on his pencil, he should pace the ground. Having ascertained the exact

* To acquire a facility in using his pencil, he may copy the various figures in Plate IX. on a larger scale, endeavouring to produce similar representations of ground. When he can do this well, let him copy the same figures with a pen on the same scale as in the plate: a little labour attentively bestowed in this preliminary study, will be more than repaid by the facility he will have acquired in representing the ordinary features of the earth's surface.

Fig. 1, Plate IX. shews the lines which should be first drawn, if the student were sketching a piece of ground similar to that represented in Fig. 3. The second figure shews the quantity of work which should be put on the field-sketch, to be afterwards finished in the manner shewn by the third figure.

distance, and corrected any errors, the road should be firmly and permanently inserted on the sketch. From the second point a fresh start to a third should be taken, proceeding as before, to correct any errors that may have been made when laying down the directions of the different objects selected to form prominent features in the sketch.

He should next proceed to sketch the slopes. For this purpose he must observe whether the ground fall across the road or wood, or only to it, and whether the fall be perpendicular to, in a diagonal direction towards, or in the same line as the road or wood. He should then estimate his distances by the eye to the extremities of the slopes, and sketch accordingly, correcting his judgment by measurement as often as he can. He should be very particular in noting whether the slopes are practicable for the movements of infantry, of cavalry, or artillery, and at what pace cavalry may ascend without incapacitating the horses for further and immediate exertion.*

As soon as he can sketch accurately on foot, he should proceed to sketch on horseback, having previously ascertained the length of his horse's paces, both in walking and trotting.

Practice will give expedition, keeping in mind that errors can alone be corrected by measurement, and the observation of objects intersecting, or nearly intersecting, each other.

* The marks commonly used to denote whether or not the ground or road, &c. be practicable for artillery, cavalry, or infantry, are inserted in Plate IX.

The second species of sketching must be made up principally from information collected from deserters, spies, people of the country, &c.; and to obtain greater accuracy, and save time, there should be several officers to sketch the ground, while the armed troops accompanying them keep the enemy at bay. Whatever number is employed, the senior makes the arrangement, allotting to each his portion, while he collects the general information.

In these sketches the distances are to be marked on the roads, &c., calculated in the paces of a man or horse, or the time required for any specified troops—infantry or cavalry—to pass from one point to another, the rate of moving per hour having been previously ascertained.

It is obvious, in the third case, that the sketch should, if possible, be finished beforehand, but if not, as it will probably be made in a hasty manner, the party making it should write in a conspicuous part what degree of dependence can be placed on its accuracy, how much he has himself seen, what he has related on the information of others, and the degree of credit to which he thinks it entitled.*

* During the Peninsular war, an officer was ordered to sketch the left bank of the Douro, from Tordesillas downwards, when the British army retreated to Rueda, previous to the battle of Salamanca; but as the enemy followed up the retreat very briskly, he could accomplish little else than what he saw as he galloped away from the advance of their cavalry. It was, however, necessary to present a sketch, and he wrote, in a large hand, across the face of it, "This sketch has no pretensions to

The last kind is a sketch of a province, department, &c. Of many countries maps exist that may be enlarged, and completed to answer the purpose, taking care to correct all visible errors, and putting in as much detail as the scale will admit without causing confusion. If no such map can be had, or those possessed are too inaccurate to answer, the resource is, either to make a rough series of triangles, observing the angles with a pocket sextant, having the exterior edge of its case quadrated as a protractor, with a small hole in the centre to place over the station, taking church-spires, windmills, obelisks, tops of hills, crags, single trees, &c. &c., as stations. Or, if the country be level and wooded, so that remarkable objects cannot be seen from each other, by taking the bearings along the roads, as far as can be seen, with the pocket compass, having its exterior limb divided as a protractor, and measuring the distances by pacing.

These instruments, with an ivory scale about 8 inches long, having scales of 4, 3, 2, and 1 inches on it, pen, ink, and pencil, are all that will be necessary for laying down the skeleton map.

accuracy, either as to bearings or distances." The superior officer to whom it was presented, exclaimed, "Then what use is it of?—you might as well have been asleep!" The *culprit* could only state the fact, that it was all he could do, and he was resolved to deceive no one. But even galloping sketches have their uses, for the one in question pointed out that there was a practicable road in that direction, stated the ravines and rivulets that crossed it, the nature of the ground over which it passed, and gave a rough guess at the distances.

A field-sketch may be very accurately and expeditiously made with the aid of a Schmalcalder compass. Then it is only necessary to ascertain with care the length of any one line from the ends of which two or more remakable objects may be discovered. The officer having laid down those points, determined by bearings taken with the compass at each end of that line, should proceed to any point where two of the objects so determined are to be seen; then taking their bearings, and protracting them on his paper, he will have determined his position, and can sketch the ground in his neighbourhood; he should then move to another spot, which he determines in like manner, by the intersection of bearings, and proceeds as before.

By having a scale and protractor always in the field, the operator is enabled to set off the angles or bearings, and lay down the distances at the moment he has ascertained them; and, in addition to performing more by this method than any other, he will have the advantage of making the work complete as far as he has gone. In bad weather when little can be done out of doors, the work may be transferred, if necessary, to other paper, a supply of which faintly ruled with parallel lines, should always be at hand; and a good, moderately sized telescope is indispensable. This skeleton map can be filled in as made, or may be deferred to the last.

Plans of this nature have been occasionally executed without instruments; a few individuals,

after a long life of practice, will effect this; but, generally speaking, time is saved, and greater accuracy ensured, by using instruments, though in the foregoing cases of sketching they may be dispensed with.

257. A reconnoissance is the process of examining a country, of which sketching is the delineation.

It is an operation to enable one to judge accurately at a simple inspection of the advantages and disadvantages of ground with regard to military movements, and is the necessary prelude to all undertakings of war.

Military reconnoissances are made under circumstances similar to those already detailed in the first part of art. 256, as applicable to sketches, and may be classed under the same heads.

258. The first class of reconnoissance consists in examining the nature of roads, to ascertain whether they are practicable for all, or only some species of troops, and their equipage; whether any and what repairs may be necessary; or whether it may not be more convenient to take other routes, and avoid them entirely.

In ascertaining the size and position of the towns, villages, mills, chateaux, houses, &c. along the line of route, and what accommodation* they

* In cantoning troops permanently, men should never be lodged singly: two at least must be together, and no house that cannot afford this can be made available. Families are not to be unnecessarily deprived of kitchen, bed-rooms in reason, and, if opulent, one retiring room.

afford for troops, either for a lengthened or temporary period; what fuel, water, provisions, forage, and means of transport of all kinds, can be procured in their neighbourhood; their salubrity or otherwise, and the general employment of the inhabitants; the lines of rivers and canals, and to what purposes they may be turned for the transport of troops, cannon, stores, or provisions; also, the best ground for forming encampments; and, in addition to these, the reconnoitring officer should make such remarks as he thinks may in any way benefit the service to which he belongs.

The reconnoissance of the road from Truxillo to Merida (Plate X.), made on the 1st May, 1809, is a sufficient guide and form.

Much depends upon the knowledge previously obtained of the country which is to be the seat of war. An obstacle overlooked may prove an impediment in the march of cavalry, or artillery, or even of large bodies of infantry; may derange a combined movement, nullify a projected simultaneous attack, and lead to the most disastrous

Large farms may be rated for the keep of five horses—small ones two. In quartering troops for a night only, five men may be allowed per house in small towns and moderately sized villages; and in making the calculation for others, the numbers are to be increased or diminished according to circumstances. This arrangement includes officers and staff. Regiments and corps should be told off to adjacent streets, to keep the men in hand. For the same reason, it is preferable even to crowd the regiment, or brigade, into one village or town, rather than have them scattered through several, though the accommodation may be greater.

results. Too much pains, therefore, cannot be taken in reconnoitering ground where the fate of nations is to be decided. To assist in these researches it is prudent to take men belonging to the country, likely to possess, from their pursuits, perfect knowledge of its localities. The best guides are, therefore, gamekeepers, foresters, shepherds, poachers, smugglers, and wood-cutters. The greater number of these employed the better; they should be kept apart, and be examined separately; magistrates, too, must be examined, and made responsible for their answers.

But as the information afforded by such persons is generally through compulsion, or for high rewards, it is not only to be regarded with the most jealous eye, but verified, when possible, by close inspection; or, at any rate, by minutely questioning the parties, to ascertain if any and what discrepancies may exist in their accounts.

Much useful knowledge may be derived as to the houses in towns and villages, and the disposition of the inhabitants, from clergymen, tax-gatherers, and inn-keepers. Let no officer despise information derived from any quarter; but at the same time be cautious how he receives it as true, or if true, whether it may be an exception to a general rule, instead of being a proof it.*

* The King of Prussia, in his "Instructions Secrètes," says, "There can be nothing more disgraceful to an officer than to make false reports, and, by way of exculpating himself, to say that [illegible] red, or had not seen clearly. On these occasi[illegible] t examine every thing with the greatest

259. In reconnoitering an enemy's position, which forms the second object of our inquiry,* it is necessary, in the first place, to ascertain the extent of ground he occupies, and, if possible, the position of his reserves, in order to estimate the number of men he may bring into action.

2dly, The situation of his batteries, whether in position or in field-works.

3dly, If there be not in his line of defence towns, villages, country-houses, rivers, &c., that may augment his powers of resistance, or, on the contrary, facilitate an attack.

care, have a clear conception and view of his subject, and be provided with a good telescope. Nothing should intimidate him; every difficulty should be surmounted. He will then be certain of what he has to report, and will not take a hundred horsemen for a regiment, or a flock of sheep for a corps of infantry, which often happens, however."

* The officer to perform this service should be mounted on a strong serviceable horse, trained to leap, and steady under fire. Let him look well to his horses' shoes before he mounts, and not only carry a spare set, with nails, &c. but learn how to put them on. It is easily done when the shoe fits the foot, by striking the nail straight and steadily, having given the point a slight bend outwards. The sabre-tache should be attached to the saddle by a couple of slings, *not* to the sword-belt, and should hold his sketch-book, the best map of the country he can obtain, prepared skin for drawing, pencils, ink-bottle, &c. counterbalancing a bag on the other side of the saddle containing his horse-shoes and as many feeds of corn as he can procure and carry without causing delay. A loaf cut in pieces, and a bottle of wine spilled upon it, is an excellent substitute for a feed of corn. A little starving will not hurt the officer, but his horse must not want. His instructions should be kept in a secret pocket in the waistband of his trousers.

4thly, How his wings are covered or protected, and the time and route to be taken to turn them.

5thly, The roads, lanes, and even by-paths, leading to his position, the bridges or fords to pass, the works and time required to render them practicable; the boats, rafts, or other means to be employed to hasten or ensure a passage, should rivers of consequence intervene.

6thly, Every height, ravine, hollow way, wood, copse, enclosure, wall, or hedge, that may cover the advance from his view, and the effect of his projectiles, or enable him to place an ambuscade.

7thly, The country in rear of his position,* if possible, that, if dislodged, the end proposed in attacking him may be immediately attained, whether it be forcing him to manœuvre to a disadvantage, cutting his line of operations, compelling him to retreat, or destroying his army entirely.

An officer, while reconnoitering close to his own position, or carrying his view over an open unoccupied extent of country, may sketch and make his remarks in safety; but it is very different when in the presence of an enemy, or on ground where woods, hills, ravines, &c. cover his advanced pickets and patrols. In the latter case, the reconnoissance must be protected by a force, large or small, according to the importance attached to its object, and the resistance expected to be met with.

* During the night previous to the battle of Vimeira the French patrolled between the British position and the sea-shore: their object probably was to make a reconnoissance.

The officer should proceed then with the greatest precautions, and always accompanied by his scouts, to examine the villages, hollow ways, and woods. If he have both infantry and cavalry, he will dispose them according to the ground, in open country covering his infantry with cavalry, and in a close country the reverse. As much for their safety, as to preserve order in his force, he will at night place his cavalry between two detachments of infantry, of which the strongest will lead if he advance, and close his march when he retires, the whole force being preceded or followed by a few mounted men as scouts. The reconnoitering officer should, while advancing, remark what woods, marshes, bridges, rivers, ravines, villages, and gardens, &c. may be taken advantage of on his return, and pre-determine the disposal of his force in the event of his retreat being impeded by the enemy. Independent of these important precautions, he will avoid dividing his force into smaller bodies, unless it may be for a moment when no inconvenience can result, and in the following cases — first, either to go himself, or send an officer, or trustworthy non-commissioned officer, into a village for information, where it may be unnecessary to take his whole force. Secondly, to make them "crown" heights, whence they may discover or verify what he is charged with reconnoitering. And, lastly, in the hope of acquiring further information by going beyond the exact point where his reconnoissance should cease; but in this case he must take measures to support them

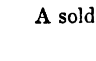
until their object be attained, when they will fall rapidly back on the main body.

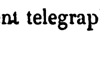
He will not, however, pass any rising* ground within his reach without at least sending one man to its summit, or, if necessary, going himself; and he must not forget, that unless it be an extraordinary distance, no halt whatever can be permitted until the object of his mission be accomplished.

In general he should avoid fighting. If, however, an enemy's detachment or post occupy a point which is necessary to be known, as much

* Two dragoons will perform this service. They should separate when within a hundred yards of the summit, one pushing on to the top at a hand-gallop, the other following steadily after. When the leading dragoon, selected for his *coup d'œil*, crowns the height, he should shade his eyes with his hand, and throw his glance rapidly, first round his immediate neighbourhood, then extend it to a distance. If all be right, let him inform his companion, or commanding officer, if within sight, by holding up his hand, or some other signal previously agreed upon. The other trooper then joins him, and after examining the ground together, they convey their information either by signal or returning to the party.

A soldier makes an excellent telegraph; for instance —


Enemy in force, retiring.


Enemy in force, advancing.


Enemy on the right, advancing


Enemy on the left, retiring;

and so on — varying the gestures to meet the various circumstances.

for itself as for what may be in its neighbourhood, and which may be rapidly forced without compromising his retreat, or leading prematurely to a general action, he will not hesitate to attack it, but with as much prudence and vigour as rapidity.*

If there should be an indispensable necessity for halting while within the enemy's reach, he will never make it at the extreme point to which he has gone, but after having returned at least a quarter of the way back to his own army; neither should he halt in a village, but choose high ground, whence he may discover any thing that may be attempted against him, and where the approaches are difficult and the retreat easy. In all cases he will shew a front of action towards the enemy, and though giving the required rest, have half his men always ready to fight, establishing small advanced posts, and videttes, with strict injunctions to keep a sharp look-out; and, if required, he will have what provisions and forage may be necessary brought from the nearest village.

During the night he must be doubly vigilant.

* "If it be desired to get possession of a height feebly occupied by the enemy, it must be approached secretly, and ascended with the greatest possible activity. The reconnoissance made, he should retire speedily, and by the most sheltered routes."—*Instructions Secrètes, par le Roi de Prusse*, p. 44. ed. 1796.

The work then proceeds to shew how the enemy may be deceived, and the best retreat made, which does not appertain to the subject now before us, but ought to be carefully studied by every officer, to whatever service he may belong, as a brief excellent essay on outpost duties.

As the chief part of the information to be collected must come from the inhabitants, a knowledge of their language is indispensable.

He should likewise know something of the country beforehand, from maps and books, that he may be able to judge of it at the first view; to see at once, and clearly, every thing that may turn to the advantage of the army with which he serves, or what, if not foreseen and prepared against, may obstruct its movements.

Roads.

260. In a reconnoissance the greatest attention must be paid to the roads. Notes should be made of their direction—width at different places, whether the same throughout or variable—their nature, whether paved, stony, through sand, clay, chalk, or over rock—even, or full of ruts, or liable to become soon damaged by the passage of troops, guns, or wagons; whether springs, streams, or other causes, may not render them partially or entirely impassable, and in what manner they may most readily be made available; the material at hand, whether fascines,* hurdles, bundles of straw

* As the principal difficulty in temporary roads consists in passing marshy or swampy ground, they may be made passable by laying down fascines, planks, or even sound timbers. When fascines are used, if the road be covered with water, or is very soft, a row of fascines should be laid across the road, and on that a row in its length, and then again a third row above both, of smaller fascines, bound by twigs or withes, in the direction of the first row, the whole covered with earth or rubbish. Long grass, reeds, or rushes, may be used in the same way, tied in

or reeds, timber, or stone walls easily levelled, &c., the number of workmen and time required for this purpose. Whether the road may be used temporarily or permanently, or whether it may not be easier to form a new road near the old one, by levelling fences and filling up ditches; whether, if the road run across the breast of a hill, it be not exposed in certain seasons to slips of soil, which is frequently the case when there is a stratum of sand; whether bounded by hedges, trees, banks, or ditches. Its undulations, if liable to be enfiladed by the enemy's works, and what means may be taken to prevent it—if exposed, at certain turnings, to his view or fire—and how, and with what, a traverse or epaulment may be advantageously constructed—the time it will take to pass—the smaller or higher roads meeting it—whence they come, and whither they lead—and on what points troops may be judiciously placed in the neighbourhood to cover the force passing along it.

Military roads * should be 20 feet in breadth,

bundles. Bread-bags filled with grass, hay, chaff, straw, heath, furze, or any other soft matter, will do; also, faggots of furze, covered with earth or gravel, or whatever is at hand.

* During the late war, artillery and carriages of all kinds were, in many instances, brought over rugged and mountainous countries, where there was no trace of roads: in fact, the operation of moving them in such situations must have been seen to be believed.

Most assuredly, the officers of the British artillery who served in the Peninsula were unrivalled in *zeal*, *abilities*, and *devotion to their duties;* and where such is the case, difficulties, obstructions, and even apparent impossibilities, vanish before them.

but ought never to be less than 16 feet, unless in cases of emergency, when 8 may do.

Defiles.

261. Their dimensions, their direction in straight or curved lines, what forms the sides and bottom, whether rocky or sandy, lined with trees or brushwood, if easily blocked up, or enfiladed, or to be defended by the enemy's light infantry. If it be absolutely necessary to pass through the defile, or whether other routes may not be chosen to avoid it. How cavalry are to pass, whether by squadrons, divisions, threes, twos, or single file—infantry, whether by companies, subdivisions, sections, or threes. If practicable for field-artillery, ammunition-wagons, and convoys. If the ground at its extremity be favourable for deploying. If the defile, or part of it, can be used to screen reserves from the enemy's view or fire. The means to be employed, and the number of artificers requisite, to clear away difficulties which nature or the enemy may have placed to obstruct a passage. The distance from, and names of, the nearest towns—the enemy's lines—and our positions.

Bridges.

262. Their dimensions, materials, and construction; the communications they establish; the readiest mode of destroying them if hurtful, or repairing them if the reverse, or to construct others; whether in the latter case it may not be more easy,

from the facilities presented by the banks, &c. (which should also be critically examined, and accurately described).

What means the enemy has of defending them, and what points may be advantageously occupied by artillery, light infantry, &c. to cover the attacking party in their advance or possible retreat. If open to all, or only certain descriptions of troops, and, as in defiles, with what extent of front these troops may cross; if they can deploy when arrived on the opposite side; and whether other passages may not be found shorter, or less exposed to observation or fire. The means at hand, or to be transported, and the number required to repair the work in case of accidents, arising either from the superincumbent pressure, the effects of the enemy's shot, sudden floods, or floating ice or timber, or, as has in many instances happened, by large rafts, fire-boats, &c.*

* That part of the bridge at St. Jean de Luz which was constructed of timber, was fired by the French in a very ingenious manner, to stay the British pursuit. When the English advance reached the bridge, about seven o'clock A.M., the first bay, or interval between the bank and nearest upright framework supporting the superstructure, was so far consumed as to render new beams and planks necessary before any passage could be effected. The repair was commenced immediately, and completed in about an hour and a half, when the second bay was discovered to be on fire, and so far damaged as to require renewal. The officer employed, while his men were repairing this also, carefully examined the under side of the remaining bays; but as the beams supporting the road-way were planked underneath as well as above, nothing appeared that gave the least indication of these being injured. The

Fords.

263. Their position—the marks which indicate them—the depth, length, and width—the volume and velocity of the water—and if it can by any means be suddenly augmented, to render the passage impracticable. If exposed to the enemy's fire, and how that fire may be silenced or rendered useless—the roads leading to, and from the ford—what chance there might be of the enemy's attacking while passing it, and from what quarter—passable for infantry, cavalry, guns, or convoys, or for all—the nature of the soil forming the bed—whether likely to be rendered impracticable by heavy rains, or melting snow—or, if near the mouth

repair of the second bay was completed about ten o'clock, and a considerable portion of infantry passed. In about an hour and a half afterwards, the third bay was discovered to be on fire, and so far damaged as to be considered unsafe. While the repair of the third bay was in progress, the remaining bay was partly unplanked, to see if the cause of this combustion, at periods varying from one and a half to three hours apart, could be discovered. Between the top and bottom planks, three boxes, about 2 feet long and 9 inches wide and deep, were found, containing a fuel, already so far decomposed by ignition that we could not ascertain its nature; and had we not discovered and removed them, this space would also have been consumed. The enemy's intention, in which they completely succeeded, was, it would appear, to destroy the different bearings at intervals, that we might not discover the extent of the injury all at once, and prepare the necessary means of repair for the whole; and doubtless they gained, by so doing, several hours' more time to get out of the way.

This account is supplied by the officer of the Staff Corps charged with repairing the bridge.

of a river, what effect the rise and fall of the tide produce upon it.

A ford should not be deeper than 3 feet for infantry, 4 feet for cavalry, and 2½ feet for artillery and ammunition-wagons.

If a ford be situated where the current is rapid, its depth should be diminished in proportion, from ½ foot to 1 foot for cavalry, and from 9 inches to 1½ feet for infantry.

Having reconnoitered a ford, it will be prudent to plant upright pickets in the stream, notched to shew the variation of the depth at different times. In mountainous countries these variations will be considerable in winter; large stones are also frequently found in fords among hills, rendering the passage difficult for cavalry, insurmountable for carriages.

In sandy countries, and where alluvial deposits are frequent, fords may be found for infantry in small numbers, but impracticable for cavalry—more so for carriages—sometimes appearing to have a firm and solid bed, but proving, on critical examination, soft or shifting.* The best have a gravelly bottom. Great care must be taken in the examination of fords, across streams or rivers threading a morass or boggy district. A brown

* The passage of the Bidassoa, in 1813, effected by part of the left column of the British army, is an example, in this branch of reconnoitering, which will teach more than any detailed rules. The officer employed to examine the fords thus writes to the author :—

" I found a great deal of difficulty in ascertaining the

rushy bottom may generally be trusted, but bright green spots are more delusive.

For these reasons no points under military reconnoissance, particularly when an attack is contemplated, require more accurate knowledge than fords; and no excuse whatever should exonerate a reconnoitering officer from not having personally examined and sounded them.

A row of pickets planted on either side of the ford, and retained by cordage, will be found useful, as well in the crossing as for the indication of its direction. When a river offers a ford of sufficient width, and the stream is rapid, it is sometimes expedient to use the cavalry to cut the current of water obliquely, and make the infantry cross lower down.

existence of any fords at all below the Irun bridge; and all the information I got, proved, in the sequel, incorrect. The river is made up of a number of mountain torrents, and, when in flood, is charged with such a quantity of sand, that if it chances to be repelled by a gale of wind at the same time, a bar, or sand-bank, is thereby formed, which serves the purposes of a ford until the next flood and storm remove it to some other place. The lower one of these, opposite the town of Fontarabia, where General Hay's brigade passed, I discovered accidentally. I was watching the enemy constructing a battery below this place on their own side, and hearing shots, turned my glass to the quarter whence the sounds came, and saw two men running as fast as they could towards the river—the French picket firing at them. The men reached the water apparently unhurt; and, to my surprise, walked across, not more than waist-deep, at least I thought so, although they kept ducking to avoid the shot from the French. I galloped to meet them; but they escaped me, as I was delayed by the intersection

When columns of attack of different arms are pushed across a ford of sufficient width, and the ground on the enemy's side admits of their deploying immediately for a charge, the infantry should pass in the centre, and the cavalry on either side covered by the fire of artillery. The infantry will, when arrived at the opposing bank, throw out skirmishers, and forming as they come up, push on to support them. The cavalry will move steadily through the water, deploy without confusion on the flanks, and endeavour, by a vigorous charge, to drive the enemy as far back as possible, to allow the remainder of the troops to pass the river without molestation.

of great drains and embankments in the water-meadows. Probably they were Spanish peasants who had been detained by the French, and were regaining their liberty. Having thus ascertained the existence of one ford, I set myself to work to verify what I had seen, and try and find another, in which I also succeeded, higher up than at Fontarabia.

" As to the troops having time to do any thing *after* they crossed, and *before* the return of the tide, *they had none*. We crossed at low water, and in *twenty minutes* there was such an influx as would have prevented a repassage. In fact, I myself (who was obliged to gallop two miles off, to start the brigade that passed higher up, and who had not seen our signal) found the water so deep on my return as to float myself and my horse. The bottom was very bad, being a movable sand. Our object was to get across and join the troops that passed above us. The attack was simultaneous along the whole position. The enemy were greatly surprised, and rapidly retired to *concentrate* on the heights in their rear, leaving the communication along the river clear to us."

Woods and Forests

264. May have great effect on the successes or reverses of a campaign. They should be examined accurately as to their position and dimensions; the sort of trees of which they are composed, whether of forest-trees, copse, or underwood—if of large timber, furnished with branches to the ground, which, blending with underwood, form a good covert for light infantry, or set far apart, the ground only covered with grass, and permitting cavalry to penetrate—if occupied by the enemy, and by what description of troops—if in front of his position, what advantage he may derive from being enabled thereby to conceal his advanced posts, and if such appears to be the case, whether it is easiest to drive them out, or turn their flanks, or cut them off by at once pushing between them and his main body—if in the line of his position, how they may cover his reserves, and if, instead of a protection, they hinder the communication, and prevent his different corps affording mutual assistance and co-operation—and if in rear of his position, woods or forests may not prove points to retire upon, from which it will take time and trouble to expel him.

As this species of reconnoissance is attended with great personal risk, dependence must necessarily be placed on the information of people belonging to the neighbourhood. They should be examined particularly (paying liberally for true reports, vigorously punishing those who have

supplied false information) about the roads and paths leading through them, if ravines, rivulets, or marshes, are to be met with either in or bordering on them. It will be also necessary to know what account the timber may be turned to, whether it will furnish the materials for making fascines, hurdles, palisades, abatis, &c. for repairing carriages, laying bridges, &c. Single trees, and remarkable edifices, gable ends of houses, spires, high chimneys, and other isolated objects that fix the attention, and serve to indicate certain points, either for the alignment, or direction of a column of troops, or advantageous position for an advanced post or artillery, should be carefully noted.

Hedges

265. Are generally thin and poor in sandy soils, but often impenetrable in strong ground. They should be examined with attention, lest they prove serious checks in an attack, hide an enemy's sharp-shooters, mask his batteries, or, if substantial and protected by a tolerable ditch in front, or low wall or bank, form an effectual entrenchment. A reconnoitering officer will, therefore, report upon their general height (supposing them of consequence,) substance, of what composed, and if simply rising out of the ground, or skirted by details of ground that may render them obstacles.

Rivers, Streams, and Canals,

266. Are to be carefully examined. If navigable, by what description of vessel, and what those

vessels will hold—their velocity per hour—what rapids, eddies, rocks, &c. present themselves—the banks, nature, and configuration of the soil—if protecting an enemy's front or wings—the best means of crossing, whether with boats, pontoons, rafts, &c.—whether the points of passage are much exposed, and how they may be covered—if near the sea, what influence the tide may have—the depth and breadth at various times of tides and floods.* With reference to the latter, it should be specified how and when they come down; as snow melting many miles off, periodical rains, letting off waters used for irrigation, &c. may materially increase the volume and force of the water just at the very moment columns of attack may be formed for crossing, or during their passage, or, worse still, when a part only of the force has crossed over.

Canals and water-courses should be examined as to the best means of drawing off the water in other directions, using or destroying them for navigable purposes, deepening their beds, or repairing their banks, to carry off artificial inundations made by the enemy. The positions of lock and sluice-gates should be accurately laid down, the best means of destroying them, and the effect their destruction might produce. In countries where rivers feed canals, and are used for irriga-

* When the allied army occupied the country south of Bayonne, in the spring of 1814, the head-quarters being at St. Jean de Luz, it was proposed to construct a bridge across the Adour, below Bayonne, to pass the left of the army in the first instance, and afterwards to keep up the communication

tion, the means of rendering them available, either by artificial inundation, damming up streams to be let off at any particular moment, &c. should be noted and reported on, as conducive to the strength of a position.

with the rear, leaving a force to invest the town, which is situated on the confluence of the Adour and Nive, three miles from the sea, it being judged inexpedient to delay advancing the main body of the army after the reduction of the fortified camp, town, and citadel.

Two officers of the Royal Staff Corps, one of whom has supplied this account and sketch, were directed to proceed from St. Jean de Luz to make their way between the front of the French camp and the sea, to observe if there existed any natural obstruction to the construction of the bridge, in the first instance, to fix the most eligible situation for it, to ascertain the breadth of the river at the spot determined on, and to suggest what precautions might be necessary to counteract any attempts of the enemy from the town, by floating heavy vessels, fire-rafts, or any thing else, down by the ebb-tide to destroy it.

They started from the English outposts with an escort of a serjeant and four dragoons, the object being concealment; and, proceeding by the dotted line, reached the mouth of the river at A without being observed; but there being a guard at B on the opposite bank, it became necessary to retire a little to avoid being seen. They then proceeded through straggling pine-trees, which, however, afforded a good cover towards D, leaving a dragoon to watch the house C, where there was a small picket, and sending the serjeant, with the two other dragoons, towards the position E, retaining only one to hold the horses. They at once walked out on the wharf wall 1 3, and, taking out their sextants, simultaneously observed the angles between each other individually and a post on the opposite bank to which a gunboat was fastened, viz. 1 3 2, and 3 1 2, immediately pacing towards each other till they met at 4. Having exchanged the above angles and paces, a shot was fired which hit the serjeant

Swampy Meadows, Marshes, Bogs.

267. Their position, dimensions, and relative causes, whether arising from land-springs, inundations of the sea, overflowing of a neighbouring river, or otherwise. How to be traversed, either by permanent or temporary roads. If there may

of the escort, who fell and was taken. All the rest now put their horses to speed, and reached their own outposts without further loss; nor was it ever said that the enemy suspected any thing beyond a common patrol.

The object of the officers changing the angles and paces forming the triangle to ascertain the breadth of the river, was, that, in case one should meet with an accident, the other might have all the information.

When the breadth of the river was afterwards accurately ascertained, it was found that the result of this hurried measurement was much nearer the truth than could have been expected.

not exist paths or roads little known, at the time disused, but capable of being put in a state of repair—if impassable, the best routes for avoiding them—the nature of the surrounding country.

In sandy and heathery ground, marshes exist in winter which are entirely dried up in summer. If old traces of wheels are here perceptible, they should be followed and sounded, when the direction they indicate may become essentially useful for the passage of troops.

Swampy meadows are generally impracticable for cavalry, sometimes even for infantry. They are easily discovered by their aspect, which offers a rank grass, among which is often seen a green and yellow moss. It may be here remarked, that plants are an indication of the nature of the soil, as well as the depth of water, and its constant presence.

Mountains, and Mountainous Districts.

268. Their position, if connected in a chain or isolated—their slopes, crests, the important points occupied by the enemy, and the best routes to be taken, either to turn or attack them (see *Roads*) —the nature of the soil—whether bare, in pasture, arable land, or wood. If it be possible, and how, an enemy pent up in a mountainous, and perhaps poor country, may be cut off from his supplies, or the general line of his operations.

Whether precipices, ravines, mountain-torrents, or other obstacles, may intervene to prevent his

wings co-operating, or acting simultaneously, and what advantage may be taken of them. The relative commands* are to be judged of as accurately as the reconnoitering officer can, supposing he has not means of ascertaining them by measurement, and he will be careful in specifying what points may be advantageously occupied by artillery, light infantry, &c. while covering an attack, and where to place videttes, look-out posts, or telegraphs. Should the enemy hold the crest of a range of hills in force, with his wings so protected that it will be impossible to turn them, and it is absolutely necessary to dislodge him from his position, nice discrimination is required to point out the line of the premeditated attack, particularly if the attacking force has first to descend a slope, cross a valley, and then mount the high ground he rests on; for during the descent, and crossing the intervening hollow, there will be a complete exposure to his fire (if within his range,) as well as a manifest exposition of the exact points intended to be assailed, and the force brought against them. Let the reconnoissance, therefore, be most carefully made from different points of view; that no inequality of the ground, whether advantageous to the enemy, or likely to impede his fire or line of sight, should be omitted in the sketch or remarks accompanying it.

* These are generally marked on the sketch by figures, beginning at the lowest, and proceeding upwards.

Open Towns, Villages, Hamlets, Farm-Houses, and their Dependencies—Isolated Houses.

269. Their situation, and if of sufficient importance to occupy a prominent place in a line of general operations—if calculated for holding a large force during a temporary period, or a small force permanently—if likely to be the quarters of outposts, pickets, &c., how they may be defended—the best means of attacking them—and, if carried, what benefit will result—the construction of the houses, the gardens, plantations, &c. that are in their vicinity—the communications through, and the roads leading to and from the neighbouring ground. Should the enemy be driven out, and endeavour to regain his position, the best means of repulsing him—of intrenching one's-self—placing convoys in safety, or forming a station for further operations.

For this last purpose, the number of the inhabitants and houses * should be ascertained, the resources † in cattle, carriages, horses, corn, and forage; the workmen and workshops of all descriptions, bakehouses and mills, whether turned by wind or water, principal churches, or other buildings that may serve as magazines or hospitals, the quantity and quality of the supplies of water, and what materials may be found for the repair or construction of carriages, pontoons, harness,

* In Catholic countries these are readily obtained from the priest.

† These from the magistrates.

intrenching tools, arms, &c. Should a small town, hamlet, or village, be occupied by an enemy in front of his line, in all probability he has rendered it as strong as he can, by palisades, barricades, overturned wagons, ditches, loop-holed houses and garden-walls, abatis, &c.; he will also have a good look-out from the church-steeple, or tops of the highest houses, to prevent surprise. It will, therefore, require some sagacity, and a good deal of boldness, to reconnoitre his position accurately. It may be possible to approach under cover of hedges, copses, garden-walls, &c. close enough to see what he is about without being discovered by his videttes or patrols; or at the dawn of day a rapid view may be had from the top of a neighbouring tree, or after dusk an individual possessed of coolness and presence of mind may crawl unperceived close up to his defences, remark their nature, and even overhear the conversation going on within; but it is sometimes necessary to make a false attack on one point to draw his attention from an opposite point where the reconnoissance may be proceeding. This attack should be made with the utmost vivacity and tremendous uproar; and the moment the object in view is obtained, a retreat should be executed with equal celerity.

Sea-Coasts.

270. In addition to the various details of which we have treated, and which must be accurately examined along the sea-coast as elsewhere, we are to consider the sea as also susceptible of becoming

the theatre of war. A reconnoitering officer will, therefore, sketch and report upon the nature and configuration of the coast—the bays, harbours, creeks, roadsteads, and anchorages—whether accessible at certain, or at all times of tide, with only some or all winds—what batteries, redoubts, forts, fortified châteaux or houses, may command landing-places—what woods or inequalities of ground are likely to hold an enemy concealed, until the moment of disembarkation, when a certain degree of confusion always exists—if bordered by cliffs, their height and shape—if by sandy beach or mud, the extent thereof at low water, how near vessels may lie with safety*—what sort of boats are chiefly used by the coasters, pilots, fishermen, &c.—and what times of tide are most favourable for the debarkation of troops, &c.

A reconnoitering officer should distinguish those parts of his report drawn from personal examination from those collected from other sources, which he may not have an opportunity of verifying. Great inland lakes are often important military features—those in America, in Italy, in Switzerland, &c. &c.

Provisions, reinforcements, &c. &c., may be forwarded by them. It is therefore very necessary to ascertain what creeks, harbours, &c. &c., exist where shipments of men or stores may be made—the depth of water, &c. &c.—whether the points of embarkation and debarkation be susceptible of

* This comes more properly under the head of maritime surveying, but nothing should be omitted in a reconnoissance.

defence, and present ground on which troops can easily deploy.

In the third species of reconnoissance, an officer charged with finding a position most capable of checking the advance of an enemy, or offering him battle, has, first, to consider the face of the country with a view of placing himself under cover by natural or artificial means, by taking advantage of defences already existing, or constructing forts, redoubts, lines, &c. where they may be required; secondly, to avoid ground where the enemy may approach with an extended front; and thirdly, to possess convenient country in rear of his position, to preserve his line of operations, and enable the component parts of his army to afford mutual and effectual co-operation and support.

It does not always happen that ground exactly suitable can be found, then, if retreat be unavoidable, advantage must be taken of the best that presents itself, and every thing which before seemed favourable to an enemy, and in the way of an attacking army, has now assumed a contrary form, is to be examined carefully, and to be turned to the best account, or destroyed.

According to these principles, a position should be selected calculated for the number of troops who are to occupy it, neither tending to cramp their exertions by diminishing their field of action, nor, by extending them too much, weaken their effect.

There is little safety in a chain of small detached posts.* In their occupation an army is

* This was our misfortune at Albuera.

broken into advanced guards and pickets—weak in many places, strong in none—easily broken through, or beaten in detail, or perhaps avoided altogether. But a strong rallying point is required, from which outposts, when attacked, may be reinforced, or where, if driven in, they may find protection; where troops may feel themselves, by their position, more than on a par with superior numbers should they be attacked; where the component parts of the army are held well together, to act with effect when directed to a particular object by the individual who commands them. There should always be this strong point—this *key* of a position.

If the troops are to halt for any time on the ground to be defended, it will be necessary to take into consideration how they are to be supplied with water, fuel, and provisions, during their halt.

If the country be mountainous, or woody, and the front and flanks difficult of access, there should be an uninterrupted command of view and fire over the surrounding ground for at least 1200 yards, at which distance field-artillery will do good service, particularly if enfilading, or taking a column in front, when the enemy cannot form his order of battle without being exposed to their effect.

The flanks should rest on points, such as rivers, artificial inundations, fortified towns or villages, swamps, mountains, ravines, the sea-coast, or impracticable forests, which cannot be turned by the enemy without making a considerable circuit, or

a flank movement, which may expose him to an attack, or by abandoning his line of operations. The reserves, and second line of battle, ought to be at least 600 yards in rear of the first, that the regiments once in line may find no obstacle if required to move by the rear to any point in the line where their presence may be wanted.

Supposing the position taken up to be eventually carried by the enemy,* their success should not cause the destruction of the army. A position for defence may be good, but its rear may not present a single object to cover a retreat. A commanding officer must be hard pushed indeed when he determines to make a final stand. An action fought is seldom an end gained; it is only the means whereby ulterior views are attained: and it has not unfrequently happened, that the party worsted in fight has eventually been the gainer, while the actual conqueror in the field has, by his own inactivity immediately afterwards, his ignorance of the beaten army's further resources, of their subsequent movements, or perhaps by a rash and uncalculating pursuit, thrown away the advantages his victory should have ensured to him.

Therefore, in reconnoitering for a retreating army, not only one position should be accurately examined, but the next in the rear of it, where the

* Our position at Waterloo had the forest of Soignies in the rear; and if the greater force of the Emperor had compelled us to retire on the 18th, before the appearance of the Prussians, the Duke would have maintained himself there with his infantry, still covering Brussels until they came up.

army may concentrate again and defend itself, or where a part of it may retire, and maintain the ground until succours arrive; or, at least, till honourable terms can be procured.

The form of the report for an advancing or retreating reconnoissance may be the same with that already given on the road from Truxillo to Merida. An additional column, however, may in some cases be advantageously introduced between the "sketch of the road," and "places on the road and near it," with elevations of remarkable objects, rendering the report more graphic; and the "observations" may extend to these extra illustrations, or a particular column of remarks applicable to them be inserted, as circumstances require.

Particular positions on either side of the route are to be sketched and reported on separately, if of importance.

A plan of the country made from these sketches, with the movements of both armies laid down on it in different colours, with particular marks for the best positions, should accompany the reports of the reconnoissance to the quarter-master-general of the army, who will probably direct the reconnoitering officer to sketch the routes for the different columns, whether advancing or retreating, to enable them to arrive together on a particular ground, either for encamping, for attack, or for defence. A form for the march of four columns is given in Plate XII., which will be a sufficient guidance.

271. In making a general reconnoissance, the last division of our subject, the combined know-

ledge of the soldier, the naturalist, and the political economist, is required, to give a comprehensive description of its military positions and communications, its resources, and the general pursuits, feelings, and interests of its inhabitants. But in these days of general peace, when actual service occupies only a small part of our time and profession, we have more leisure for study, more incentives to acquire general knowledge, than any other body of professional men. The pen and pencil have, during a long peace, superseded the sword, in making a way for him who wields them to honour and distinction.

We should then enter freely, fully, and heartily on our profession, first learning implicit obedience, that at a future period we may know how to command; and making ourselves masters, as opportunities are afforded, of chemistry, natural history, mechanics, and, above all, languages. A diplomatist is not more necessarily a linguist than a soldier.

In a work of this description no particular instructions can be given for making a general reconnoissance beyond what has been said under this head in sketching, and the annexed form for methodising the operation; but an officer can only qualify himself for undertaking such a task by reading, and making notes of what he reads; by observing the country through which he passes with a military eye, and by making the daily practice of his pen as much a point of duty as his attendance at parade.

APPENDIX.

NOTE I.

PROBLEMS, &c. RELATING TO THE SCIENTIFIC METHOD OF DEFILADING WORKS.

1. HAVING explained the practical methods of defilading field-works, we shall now proceed to shew in what manner they may be defiladed in the closet, with the aid of a plan only; a knowledge of which mode of defilading works is essential to the thorough understanding of this subject.

2. In the graphic operations relating to defilement, the outline of the proposed fortress or work is laid down on a plan, which should also contain all the ground within 2000 yards of the most advanced works. The vertical dimensions or profiles are supplied by numbers or scales, shewing the distance of the several parts of the fortress, below a horizontal plane supposed to pass ten yards above the highest point of ground contained in the plan, and which is called the *plane of comparison*.

The ground is represented by horizontal contours, or sections Fig. 64, made at equal vertical distances, (generally one yard), and at the side of each contour a number is written, shewing its depth below the plane of comparison.

If an inclined plane were represented in the manner above described, the horizontal sections would be parallel equidistant right lines *a a*, *b b*, &c. Fig. 65, the distance between these lines decreasing in propor-

tion to the steepness of the plane; so that if the plane were vertical, all the horizontal sections would be projected under one line: the horizontal trace or projection of a vertical plane is therefore a right line.

3. Any line C D perpendicular to the horizontal sections of an inclined plane, is evidently drawn in the direction of the greatest slope of that plane, and is divided into equal parts by the sections *a a*, *b b*, &c.: this line, so divided, is called the *scale of the plane*, and is used to represent the inclination of the plane to which it belongs.

The scale of a plane C D Fig. 66, being given, to find the height of any point O on the plane; let fall from the given point a perpendicular on the scale, and the intersection will shew the height of the point required. A line A B is usually drawn perpendicular to the scale, and parallels to this line may afterwards be drawn from any points of which the heights are required. Previous to entering further on this subject, it is necessary to understand perfectly the following Problems:

4. Problem I.—Three points on an inclined plane being given, to find the scale of inclination. Let A, B and C Fig. 67 be the given points, their distances below the plane of comparison being 16, 13, and 17 yards; join the three points by right lines A B, B C, and divide each line into as many equal parts as there are units of difference between the points which terminate it, viz. A B into three, and B C into four equal parts; join any two similarly numbered points, as H R: this line being equidistant from the plane of comparison at the two points H and R, must be horizontal, and being drawn on the plane, is, therefore, one of the horizontal sections of the given plane.

The scale of the plane is perpendicular to the horizontal sections (art. 3); draw then D E perpendicular to H R; and, to graduate it, draw parallels to H R through the divisions marked on either of the lines A B, B C. The line D E thus graduated, is the scale sought.

5. Problem II.—Given the scales of inclination of two planes, to find their intersection.

Case 1.—When the scales of inclination are not parallel.

Let A B, C D Fig. 68 be the given scales. Draw horizontal lines through any two points on one of the scales A B, similarly numbered to two points on the other plane, and also through the corresponding points on the scale C D. The points of intersection of these lines being common to both the planes, if a line E F be drawn through them it will shew the intersection required. If the opening of the angle formed by the horizontal sections be turned towards the ascending points of the scales, the line E F will form a ridge; if turned in the contrary direction, it will form a gutter or furrow.

Case 2.—When the scales of inclination are parallel.

In this case, the horizontal lines drawn on the surfaces of the two planes being parallel, cannot intersect each other; but as the intersection of the planes must, therefore, be perpendicular to both scales, it will only be necessary to find one point of that intersection, which may be readily done by constructing vertical sections of both planes, in the following manner:

Let C D, B A Fig. 69 be the given scales; it may be at once seen that their intersection lies between the 15th and 19th divisions. Take any point on one side

of the intersection (19), and draw horizontal lines through that point of division of both scales, making *c d* equal to 19 *a*; from *a*, draw a line to any point B 14, on the other side of the intersection; through the corresponding point of the other scale draw a horizontal line, intersecting the first scale in *e*; join *d e*: the intersection of the lines *a* B, *d e* will be the point sought; through which draw P L perpendicular to the given scales: the line P L is common to both the planes, and is the intersection required. The distance 19 *a*, may be taken of any convenient length.

6. Problem III.—To find the intersection of an inclined plane with a given surface, represented by horizontal contours.

Let A B Fig. 70, be the scale of the plane, and C D E the given surface; produce the horizontal sections of the plane until they cut the similarly numbered contours of the given surface; join the points of intersection *a b c d*, &c. for the intersection required.

The vertical distance between any point X, of the surface, and the section made by the plane is thus found:—From the given point let fall a perpendicular on the scale A B; now, the number corresponding to X on the surface is 14, and on the plane $14\frac{1}{2}$; consequently the point X is half a yard above the section made by the plane. The difference of level between any number of points may be found in a similar manner, and data be obtained for calculating the volume of the mass cut off by the given plane.

7. Problem IV.—To construct the section of a surface cut by a vertical plane.

Let A B Fig. 71 be the horizontal trace of a *vertical* plane; then imagine it also to represent the plane

of comparison in a vertical section; from the points of intersection of the line A B with the contours of the given surface, let fall perpendiculars *a*, *b*, *c*, *d*, &c., equal to the distances of those contours below the plane of comparison; a line drawn through the ends of the perpendiculars will shew the section required.* If the trace of the vertical plane were a right line, drawn in the direction A B′, then it would be necessary to determine other intermediate points, in addition to the intersections of the vertical plane with the horizontal contours, to get a true representation of the section.

8. Problem V.—To construct the intersection of a vertical plane with an inclined plane.

Let A B Fig. 72 be the horizontal trace of the vertical plane; then suppose it to represent the plane of comparison in a vertical section; produce any two horizontal sections of the given plane until they intersect A B; from the points of intersection *a* and *b*, let fall perpendiculars *a c*, *b d*, equal to the distances of the sections used, below the plane of comparison: a line drawn through *d c* will shew the required intersection.

9. Problem VI.—To find a horizontal line on a plane, containing on its surface a given inclined line, and forming with the horizon a given slope or angle.

Let A B Fig. 73 be the given line, and suppose the perpendicular and base of the right-angled triangle which measures the slope to be 3 and 2.

* In constructing sections formed by vertical planes, if the scale of the plan be so small as to render the differences of level not sufficiently apparent, any larger scale may be made use of to measure the vertical distances of the section.

At any point M, on the line A B, of a given height, with a radius taken from the scale of the plan, equal to the base of the given triangle, describe a circle.

If we imagine the point M to be the summit of a cone three yards high, and the described circle to be its base, then the plane sought must evidently be a tangent to that cone. The base being three yards below the point M, find a point L on the given line, also three yards lower than M; from L draw a tangent to the base of the cone, and it will be a horizontal section of the plane sought.

Oblique scales are sometimes made use of; the divisions of which are required to be of a given length. To construct a scale of this description, draw a parallel to L T, through any other division of the line A B; from any point P on this line, with a radius equal to the difference of level between the sections P and L T, multiplied by the given length of each division of the oblique scale, describe an arc cutting the line L T; draw a line through P, and the point so found, for the direction of the oblique scale required, which may then be graduated as in the figure. A horizontal line should always be drawn at one end of an oblique scale. This description of scale is made use of to represent the superior and exterior slopes of parapets.

10. Problem VII.—To find the scale of a plane that shall contain on its surface a given right line, and be a tangent to a given surface.

Case 1.—When the given line is inclined.

Let A B Fig. 74 be the given line, and *aaa*, *bbb*, the given surface; draw tangents C E, D S, from the several points on the line A B, to the similarly numbered contours of the given surface. That tangent

which forms with the given line the smallest angle on its descending side, will be a horizontal section of the plane required; draw D H parallel to C E, and a division of the scale of inclination is obtained.

If, instead of the tangent C E, the tangent D S were used to construct the scale, the plane thus found would cut off a portion of the given surface *a a a*, contained within the angle E C U, and would therefore not be a tangent to the given surface. This plane is called the *plane of site*, or *regulating plane;* and the line A B *is the line of site*.* It would often happen that from the slight inclination of the given line, no numbers could be found on it corresponding to those on the contours to which tangents ought to be drawn: in this case assume a point of contact, as *a* Fig. 75, and draw a line from that point to any division of the given line; graduate this line, and join a corresponding number on it and on the given line, for a horizontal section of the plane sought; construct the scale as in the figure; then, if one of the horizontal sections of the plane be not a tangent to a similarly numbered contour, while all the other sections leave the corresponding contours in front of them, assume a fresh point of contact, and proceed as before.

Case 2.—When the given line is horizontal.

11. Let A B Fig. 76 be the given line, and suppose its distance below the plane of comparison to be 16; parallel to A B draw *a b*, *c d*, and *e f*, tangents to the contours of the given surface. If the line A B were moved forward, preserving its horizontal position, it would evidently touch the ground in the direction of the curve *v t s*, and coincide with each of

* *Fr.* Ligne de site.

the tangents *a b*, *c d*, *e f*, in succession; generating a cylindrical surface which we may suppose to be represented by the line A B, and those several tangents. At any point C, in the line A B, draw C E perpendicular to A B, and also from the same point any line C D.

If we imagine C E and C D to be the two sides of a triangular plane, and that C E is a tangent to the cylindrical surface before described, it will evidently touch that surface, in the same point or points, whatever the inclination of C D may be.

From C set off on C D as many equal divisions as may be necessary to shew its assumed inclination; join the points on the line C D with the similarly numbered points of contact of C E, and the tangents *a b*, *c d*, and *e f*. The line which forms the smallest angle with C D, on the descending side of that line, will indicate the point of contact of C E with the cylindrical surface, and consequently one of the points of division of the scale sought.

12. Problem VIII.—To find the scale of a plane which shall contain on it a given point, and be a tangent in two points to a given surface.

Let P Fig. 77 be the given point, its distance from the plane of comparison being 8; from P draw lines P A, P A′, &c.; then through P draw any other line P B, and mark divisions on it, to shew its assumed inclination. By proceeding in the manner described in art. 11, we may find the points where the several lines P A, P A′, &c. touch the given surface. Graduate all those lines, viz. divide each into as many parts as there are units of difference between its respective point of contact with the ground, and the *given* point P. The point P may then be conceived

to be the apex of a solid angle, of which the lines P A, P A′ &c. are the ridges and furrows; make a horizontal section of this solid angle, *i. e.* join a set of similarly numbered points on the ridges and furrows before mentioned; draw tangents to the horizontal section so made: in the example there are three tangents C D, E F, and I R, any one of which may be taken as a horizontal section of the plane sought. That tangent which is most distant from the given point, will give the plane of least inclination. If the horizontal section had presented only one salient angle towards the given point, a vast number of planes might have been found; in this case, the one which most nearly coincides with the ground to be occupied by the works, should be selected.

APPLICATION OF THE PRECEDING PROBLEMS, &C.

13. In art. 62 it is stated, that the maximum of relief for the parapets of field fortifications is twelve feet. Let us suppose then, the base, or line of site of a work, to be horizontal, and let A B Fig. 78 represent the trace of a vertical plane perpendicular to the line of site, meeting the surface of the ground in P, and forming the section P *m n*; let *c* be the point of contact of the same plane with the line of site, D E the vertical line corresponding to the salient angle of the proposed work, and *c g* the vertical trace or section of the plane of site: the plane of defilement will be parallel to *c g*, and pass eight feet above the point of command.*

* The point of command is the point of contact of the plane of site with the ground, not the highest point of the ground; this latter being termed the point of culmination, or culminating point.

If mf exceed twelve feet, the relief of the salient will be greater than the maximum allowed. Another line of site must then be tried, which we shall still suppose horizontal, and meeting the vertical plane in a point h; the trace of the corresponding plane of site will be the line $h\,t$, that of the plane of defilement the line $r\,s$. If $m\,v$ be less than twelve feet, the new plane of site will be within the required limits. This plane must necessarily cut the ground in a part of the exterior space near the gorge; there will, therefore, be a portion of that space from which the interior of the work is not completely defiladed. If it be necessary to defilade the interior from the part so cut off by the plane of site, the operations detailed in art. 21 must be performed: if unnecessary, then it is required only that the command of the work over the ground from which it is not defiladed shall be five feet; the depth of the line of site below the plane tangent to the same ground, must therefore never exceed three feet.

14. The inconvenience of being commanded by neighbouring heights, does not always require even an increased relief; for it may easily be conceived that the natural plane of site of a proposed work might be such, that if produced it would pass above all the higher ground in front of it. Though a commanding position is undoubtedly superior to a commanded one, yet if the rules of defilement have been properly applied in the construction of the fortifications, the defenders will find themselves as perfectly screened from the view of the enemy, in a fortress commanded by the surrounding ground, as if that fortress were constructed on a plain.

The following examples of the application of the principles of defilement to field-works will, it is pre-

sumed, be sufficient to render them perfectly intelligible.

To Defilade Open Works.

15. The most simple open works are the redan and the lunette. Let B C D Fig. 79 be the plan of a redan, and A B C D E that of a lunette: the first operation is to fix the limits of the ground from which it is necessary to be defiladed.

We shall suppose that the boundary of these limits is, 1st, an arc of a circle described from the salient C with a radius of 300 yards; 2dly, for the redan the lines B R and D S: for the lunette, the lines A K and E I, perpendiculars to the extremities of the crests of the respective works, produced until they meet the arc previously described. The limit in height for the exterior space we shall suppose to be eight feet, in order that the plane of site tangent to the exterior space, and parallel to the plane of defilement, may also be the plane of the terreplein. The second operation is to ascertain whether the commanding points are situated in front or in rear of the faces produced. By ground in front of a face, is understood that ground on which the face fires, and which lies on the same side of that face produced. By ground in rear of a face, is understood all the ground not comprised in the first definition within the limits of defilement before described. This distinction leads to the consideration of two different cases:

1st. When the commanding points are situated in front of the faces and flanks.

2d. When those points are situated in rear of the same faces and flanks.

16. *Case* 1.—Let B C, C D Fig. 79, be the plan of the crests of a redan. First, it is necessary to en-

deavour to regulate the relief of the crests so that they may be in the same plane of defilement; *i. e.* a plane passing eight feet above the exterior surface. In order to perform this operation, assume the height of any point O situated a little in rear of the gorge, and determine the plane of site as in art. 12. From the distances of the points B, C, D on the plane thus found, below the plane of comparison, subtract eight feet for the distances of those points of the crest below the latter plane.

17. If the conditions required by art. 13 are not fulfilled, then assume a distance for the point C Fig. 80, below the plane of comparison, and find the points of contact of two tangents to the given surface, drawn in the direction of the faces B C and D C produced (Problem VIII.), and to which the point C is common. Graduate those tangents, and find the scale of the plane containing them on its surface. This plane is called the *plane of sub-crests*. The points B, C and D on the plane of sub-crests should be higher than the points of the ground beneath them, but this difference must not exceed four feet.

Let *a b* Fig. 80 be the plane of sub-crests, and suppose this plane to cut the given surface in the direction of the curve *g h i m n*, within the sector formed by the prolongation of the faces B C and D C. It is evident, from an inspection of the figure, that the interior slopes cannot be seen from any part of the exterior space; it will then be sufficient to defilade each face from the ground in front of it; in order to do which, graduate the prolongations of the faces B C and D C, according to the given scale *a b*, and proceed to find the planes of site as directed in Problem *VII.* art. 10. There will then be two scales of inclina-

tion for the planes of site; find their intersection C H, and also the intersection of those planes with the terreplein of the work. The position of these latter intersections with respect to C H will shew whether the natural plane of site can be taken, and, if not, to what extent it will be necessary to excavate the terreplein.

The method of proceeding above described, is adapted to the case in which it is required to defilade a work already constructed, without increasing the relief.

18. Let A B C D E Fig. 79 be the outline of a lunette, and suppose those five points are required to be placed in the same plane of defilement, or the five corresponding points of the sub-crests in the same plane of site, tangent to the exterior surface. As the plane of site ought to pass above all the ground in front of the line K I, we should first determine the heights of the points A and E of the gorge, which points are projected on the line K I.

For this purpose, construct the section of the ground made by a vertical plane, of which the line K I is the horizontal trace, Prob. IV.; let *r a e v* be this section, then any line *x y* not more than four feet above it may be taken as the line of site; but it is in general more convenient to choose the line H T, a tangent in two points to the section *r a e v*; graduate the line K I to represent the line of site H T, and determine the plane of site as in Problem VII.

19. *Case* 2.—First solution. Determine the relief of the crests B C, C D Fig. 80, so that their prolongations may not intersect the exterior space (art. 17). Let *a b* be the plane of the sub-crests intersecting the ground in the direction of the curve *g h i m n*, con-

tained within the sector formed by the prolongations of the faces B C and C D.

Find the planes of site and defilement of the faces B C and C D (art. 17), keeping the crest of each flank in the same plane as the adjoining face. The planes of site and defilement being parallel, and the divisions of their scales equal, they may both be represented on the same scale; it is only necessary to subtract eight feet from each number on the scale of the plane of site, to have the corresponding height of the plane of defilement; but, as the numbers on the scale of the latter plane would then contain fractions, it is more convenient to mark a fresh set of points, where the whole numbers of that plane fall. If the relief of the flanks be regulated in the manner above mentioned, the interior slope of the flank A B will be masked by the face C D, and of the flank D E by the face B C, as far as the lines A D S, E B R. It then remains to determine whether the flanks cover each other from the view of the ground contained between the lines E R, A S, and the line K I, the boundary of the ground from which it is necessary to be defiladed. If this be not the case, then a traverse must be erected extending from the salient to the gorge of the work.

20. The relief of the flanks may also be thus regulated:

Keep their sub-crests iu the same plane as the sub-crests of the faces, then their interior slopes will be seen only by the portion of the exterior space *g h i m n*, cut off by the plane of the sub-crests. In order to cover them from the view of this portion, two traverses are required.

Let B F Fig. 80 be the direction of the crest of the traverse intended to defilade the flank A B. To

determine its length, from the extremity of the flank A draw A *m* tangent to the curve *g h*, &c., leaving all that curve in front of it; the point where the lines B F and A *m* intersect will be the extremity of the traverse, the height of which is to be found as in art. 21.

It may be remarked, that as the prolongation of the crest of the flank A B intersects the space *g h i m n*, it will be necessary to produce the traverse on the parapet until it meets the line A *o*. In whatever manner the relief of the flanks may be regulated, the terre-plein must always be determined by the two planes of site previously found. The intersections of these planes with the ground should therefore be constructed. And unless they are in rear of the faces only, it is a sufficient proof that the operations of defilement have been incorrectly executed.

21. When the plane of the sub-crests intersects the exterior surface in the direction of the curves *f g h i*, *a b c d e*, and *k l m n* Fig. 81, the two latter curves, situated in rear of the faces produced, determine the planes of site as in art. 17, defilading each face from all the ground in front of it; and let the crest of each flank be kept in the plane of defilement of the adjacent face.

In order to determine the traverse required to protect the faces from reverse fire, find the scales of planes containing on them the sub-crests of B C and C D, and tangent to the ground in rear of those faces.

In graduating these scales subtract ten feet from each division, in order that the plane of defilement of the traverse may pass two feet above the crests of the parapets; this height being required to protect the men mounted on the banquettes from reverse fire. These two scales will represent the reverse planes of

defilement required to determime the height of the traverse.

Let C F be the horizontal projection of the crest of the traverse, then that reverse plane of defilement which gives the greatest command for the traverse, is the plane required. The height at the point C being common to both the planes, it will only be necessary to compare the heights at the point F, in order to find which of the reverse planes is to be used. If the sub-crests of B C and C D were in different planes, then the heights at the point C should also be compared, because the crests of the faces at that point would not then be on the same level; the traverse would, however, cause this inconvenience to disappear.

In constructing the work, the planes of site of the portions A B C F, F C D E, must be continued to the traverse; so that if C H were the intersection of those planes, it would be necessary to produce the plane of site of the portion A B C F, through the space contained within the triangle H C F; otherwise that part of the terreplein would not be properly defiladed.

If it were required to give the traverse the least possible relief, it should be constructed on the intersection of the reverse planes of defilement.

22. It is necessary, in order to defilade completely the interior slopes, to continue the traverse up to the salient C; but this would render it impossible to place any defenders at the salient angle, which is always particularly desirable in field-works. To remedy this evil, the traverse is sometimes discontinued near the salient angle, as at the point L, and turned perpendicularly on one or both of the faces. Another method of correcting this defect is, to construct a bonnette extending from C to *r*. A bonnette is the name

given to a parapet made higher at the salient angles than in other parts.

When the bonnette is only intended to protect the faces from enfilade fire, it should extend sufficiently far on each face to cover the banquette and its slope, or to cover the terreplein required for a piece of field-artillery. The bonnette should be made about one yard high (art. 88, *Field Fortification*).

23. *Second Solution.*—Let C F Fig. 80 be the direction of the crest of the traverse intended to cover the two terrepleins; find the heights of the point F in the planes of site A B C F and F C D E.

Consider these points as the summits of two triangular planes, the one tangent to the ground in front of the flank A B and face B C, the other tangent to the ground in front of C D and D E.

These two planes will be the planes of site for the two portions of the work, and consequently their intersections with a vertical at the point C should be on the same level.

The height of the traverse may be determined as in art. 21.

24. In treating of the defilement of open works, they have been supposed to be isolated; but it is necessary that they should be supported by troops in their rear, or be placed in such positions as may prevent their being turned.

In the first case, the vigour of the defence would greatly depend on the possibility of their garrisons being efficiently succoured.

Not only should the works therefore be defiladed, but also all the ground over which the troops destined to support them may be required to advance;—a condition difficult to fulfil, unless the ground itself

afford cover for the troops, advancing from the principal works to the gorges of those in front.

DEFILEMENT OF ENCLOSED WORKS.

25. We will select, as an example, the most simple enclosed work—viz. a square redoubt. Three cases present themselves for consideration.

Case 1.—When the plane or planes of site do not intersect the exterior space, within the limits of defilement.

This case occurs when the work is constructed on a plain, and in mountainous countries if the redoubt be placed on a height, or on an inclined surface, which, being prolonged towards the heights, passes above the commanding points, and on the side of the plain intersects the ground only at a great distance.

26. *Case* 2.—Let A B C D Fig. 82, be a square redoubt, to be constructed on a site commanded by the surrounding ground. The relief of the crests must be so regulated (art. 17) that the prolongations of the sub-crests may not intersect the exterior space.

It will generally happen that the plane or planes of the sub-crests will intersect the surface of the earth, and this cannot occur without exposing two or more faces of the redoubt to be seen in reverse.

Let *a b c d* be the intersection of the plane of the sub-crests with the ground; the faces A D and D C being seen in reverse, a traverse or parados must be erected in the direction A C. To defilade the part A B C, determine separately the planes of site for the faces A B and B C with reference only to the ground in front of them (art. 17).

The part A D C will have for its plane of site the plane of the sub-crests A B, C D, which plane does not

intersect the ground in front of those faces. The traverse should be discontinued near the salients A and C (art. 22).

To determine its height it will be sufficient to find the height of one or more points. Let the line D *s t* or D *p* be in the direction which appears to offer the greatest relief for the traverse; find the point of contact of a tangent to the given surface drawn in the direction of one of the lines D *s t* or D *p*; graduate that tangent, and place the crest of the traverse on a parallel plane ten feet above it.

27. Let *a b c d*, *e f g h*, be the projections of two intersections of the sub-plane of the crests with the exterior surface; all the faces of the redoubt will then be seen in reverse, but the traverse A C will cover them from reverse fire. It is necessary, in this case, to repeat the operations detailed in the preceding article, in order to determine the height of the traverse required to cover the faces A B and B C; and that tangent is to be used for the construction which gives the greatest relief for the traverse. The plane of site will be determined for each face as in the last article.

28. Sometimes the following more simple plan may be resorted to:—When the redoubt has a very evident command over the ground contained in the sectors M A T and P C Q, and the points of command are situated within the sectors N B O and S D R, then determine the relief of the points A and C only; find the line of site corresponding to those points, and consider it as being common to both parts of the redoubt separated by the traverse.

29. If the planes of the sub-crests intersect the ground in all the sectors formed by the prolongations of the faces, or in three only, it will be necessary to

construct a traverse in the form of a cross in the direction of the diagonals of the redoubt.

30. Let *m n o p* Fig. 83 be the intersection of the plane of sub-crests with the ground; the faces A D and B C will be exposed to slant fire, and the face D C be seen in reverse.

The first may be covered by the traverses A E, and B F, the last by the parados G H; the ends of the traverses and parados being extended one yard beyond the points E, F, G, and H.

The terreplein of the part A E G H F B C D will be in the sub-plane of the crests of A D, D C, and C B, because that plane does not intersect the ground in front of those faces; the terreplein of the remaining space A B F H G E will be kept in a plane of site, containing on its surface the sub-crest of A B, and tangent to the ground in front of that face. There will then necessarily be breaks in the terreplein, in the directions G E and H F.

The position of the parados should be such that this difference of level may not exceed one yard.

If the relief of the traverses B F and A E, were required to be very great, in order to defilade the faces B C and A D, those faces may be defiladed in portions; a sufficient relief being given to the traverses B F, *b f*, to cover the parts B *b* and *b* C; A E, and *a e*, covering in like manner A *a*, and *a* D.

31. *Case* 3.—When the sub-crests intersect the ground in the direction of their prolongations.

This cannot always be avoided; for, suppose that it is required to construct a redoubt on a plain in front of a hill, the crest of which is represented by the line X Y Figs. 82 and 83, one of the salients may be turned towards the hill, as in Fig. 82, or one of the

faces Fig. 83. In the first case, all the sub-crests will intersect the hill; two faces will be seen by slant and two by reverse fire. In the second case, two sub-crests only intersect the hill; one face is seen in reverse, and two are enfiladed; while one can neither be seen in reverse, nor enfiladed. If, then, it were necessary to trace the work in the first manner, the angles A and C should be made as small as possible, in order to diminish the length B D; if traced in the second manner, the faces A D and B C should, for a similar reason, be made short.

NOTE II.

To find the solidity of the frustrum of a cone; Fig. 127.

Given $BC = a$
$BE = l$
$EF = c.$

Let $EG = x$. Then $a : c :: l + x : x$,
and $a - c : c :: l + x - x : x :: l : x$

$$x(a - c) = cl$$

$$x = \frac{cl}{a-c} = \text{height of cone cut off.}$$

The solidity of the frustrum will be equal to the solidity of the whole cone, minus the cone cut off.

To find the solidity of the whole cone, let p equal the ratio of the circumference of a circle to its diameter $\left(\frac{22}{7}\right)$.

$$\text{Then } \frac{pa^2}{3}\left(l + \frac{cl}{a-c}\right) = \text{solidity of cone;}$$

$$\text{viz. } \frac{pa^2}{3}\left(\frac{al + cl - cl}{a-c}\right) = \text{solidity of cone.}$$

$$\text{or, } \frac{p a^2}{3} \left(\frac{a l}{a - c}\right).$$

The solidity of the cone cut off is $= \frac{p c^2}{3} \left(\frac{c l}{a - c}\right)$.

The solidity of any frustrum of a cone of which the radii of the circular ends and height are known, is therefore equal to

$$\frac{p a^3 l - p c^3 l}{3 (a - c)} = \frac{p l}{3 (a - c)} (a^3 - c^3),$$

which, effecting the algebraical division, gives

$$\frac{p l}{3} (a^2 + a c + c^2).$$

To find the content of the crater of a common mine, we have $a = l$, and $c = \frac{l}{2}$; which values being substituted in the general expression, we shall have $\frac{p l}{3} \left(\frac{7 l^2}{4}\right) = \frac{7 p l^3}{12}$. But p is $= \frac{22}{7}$; therefore, $\frac{7 p l^3}{12} = \frac{7}{12} \times \frac{22}{7} l^3 = \frac{11}{6} l^3$; viz. the solidity of the crater is equal to $\frac{11}{6}$ of the cube of the line of least resistance.

NOTE III.

Let us suppose that a horizontal gallery has its superior surface placed at the distance d, below the horizontal plane passing through the centre of the mine, and its side sheeting at a distance c, from the vertical plane passing through the same centre; if from this centre a perpendicular be let fall on the edge of the gallery nearest to the charge, the rupture will extend on each side of the perpendicular to a distance represented by

$$\surd\left(\frac{49}{16}l^2 - \frac{49}{32}d^2\right) - c.$$

For, let A B H, Fig. 128, be the ellipsoid of rupture, then we have,

Given $AC = a = \frac{7}{4}l$ $\quad$ $CE = c$

$CB = b = l\surd 2$ $\quad$ $CF = d$,

to find D H and C H, &c.

From H erect H I perpendicular to the transverse axis, and let $CI = x$.

$$\text{Then } a^2 : b^2 :: \overline{a+x}\,.\,\overline{a-x} : d^2$$

$$a^2 d^2 = a^2 b^2 - b^2 x^2$$

$$x^2 = \frac{a^2 b^2 - a^2 d^2}{b^2} = \frac{a^2(b^2 - d^2)}{b^2}$$

$$x = a\surd\frac{(b^2 - d^2)}{b^2} = a\surd\overline{1 - \frac{d^2}{b^2}};$$

$$\text{but } DH = x - c = a\surd\overline{1 - \frac{d^2}{b^2}} - c.$$

In which expression, substituting the known values of a and b, we get

$$DH = \surd\left(\frac{49}{16}l^2 - \frac{49}{32}d^2\right) - c.$$

The length of gallery destroyed will therefore be equal to double this distance, and the sub-horizontal radius of rupture with respect to the gallery will be represented by

$$\surd\overline{\frac{49}{16}l^2 - \frac{17}{32}d^2};$$

$$\text{for } FH = c + DH = \surd\overline{\frac{49}{16}l^2 - \frac{49}{32}d^2}$$

$$CH^2 = FH^2 + FC^2 = \frac{49}{16}l^2 - \frac{49}{32}d^2 + d^2$$

$$C\,H = \sqrt{\frac{49}{16} l^2 - \frac{17}{32} d^2}.$$

Suppose, now, a vertical shaft at the distance c from the centre of the charge, the extent of the shaft destroyed by the explosion of the mine will be represented by

$$2\sqrt{\frac{(98\,l^2 - 32\,c^2)}{7}};$$

for, let A E I H Fig. 129 be the ellipsoid of rupture, we then have given

$$A\,C = a = \tfrac{7}{4}\,l, \qquad C\,E = b = l\sqrt{2},$$
$$C\,D = c\text{: required } H\,I \text{ and } C\,H.$$

Let $B\,H = x$. Then $a^2 : b^2 :: \overline{a+c}\,.\,\overline{a-c} : x^2$

$$x^2\, a^2 = b^2\, a^2 - b^2\, c^2$$

$$x = \sqrt{\frac{b^2\,(a^2 - c^2)}{a^2}} = b\sqrt{1 - \frac{c^2}{a^2}}$$

Therefore, $H\,I = 2\,b\sqrt{1 - \frac{c^2}{a^2}}$; or, substituting the values of a and b,

$$H\,I = 2\sqrt{2\,l^2 - \frac{32\,c^2}{49}} \text{ or } \frac{2\sqrt{98\,l^2 - 32\,c^2}}{7}$$

The distance of the charge from each of the extremities of the broken part, viz. the sub-horizontal radius of rupture, with respect to the shaft, will be

$$\sqrt{\frac{(98\,l^2 + 17\,c^2)}{7}}$$

for $C\,H = \sqrt{c^2 + x^2} = \sqrt{c^2 + b^2 - \frac{b^2\,c^2}{a^2}}$;

or, substituting the values of a and b,

$$C\,H = \sqrt{\frac{17}{49}c^2 + 2\,l^2} \text{ or } \frac{\sqrt{(98\,l^2 + 17\,c^2)}}{7}.$$

In general, let r be the radius of rupture in the direction formed by the angle φ and a vertical line passing through the centre of the charge; then

$$r = \tfrac{7}{4}\,l\,\sqrt{\left(\frac{1 + \tan^2\varphi}{\tan^2\varphi + \frac{49}{32}}\right)};$$

For in Fig. 130, given $A\,C = a = \frac{7}{4}\,l$,

$$C\,B = b = l\,\sqrt{2}, \text{ angle } H\,C\,F = \varphi,$$

to find $C\,F$.

$$\text{Put } F\,E = y; \text{ then } C\,F = y\,.\sec\varphi.$$

$$\text{Therefore, } C\,E = \sqrt{(y^2\sec^2\varphi - y^2)}$$

$$\text{But } a^2 : b^2 : : \overline{a + C\,E} \times \overline{a - C\,E} : y^2$$

$$a^2 : b^2 : : a^2 - y^2\sec^2\varphi + y^2 : y^2$$

$$a^2\,y^2 = a^2\,b^2 - b^2\,y^2\sec^2\varphi + b^2\,y^2$$

$$a^2\,b^2 = (a^2 + b^2\sec^2\varphi - b^2)\,y^2$$

$$y^2 = \frac{a^2\,b^2}{a^2 + b^2\sec^2\varphi - b^2}$$

$$y = \frac{a\,b}{\sqrt{(a^2 + b^2\sec^2\varphi - b^2)}} = a\,b\,\sqrt{\left(\frac{1}{a^2 + b^2\sec^2\varphi - b^2}\right)}$$

$$\text{But } \sec^2\varphi = 1 + \tan^2\varphi.$$

$$\text{Therefore, } \sec\varphi = \sqrt{1 + \tan^2\varphi}.$$

Substituting the value of $\sec^2\varphi$ in the value of y, we get

$$y = a\,b\,\sqrt{\left(\frac{1}{a^2 + b^2\tan^2\varphi}\right)}$$

$$\text{But } C\,F = y\,.\sec\varphi.$$

Therefore, $C\,F = a\,b\,\sqrt{\left(\frac{1 + \tan^2\varphi}{a^2 + b^2\tan^2\varphi}\right)}$, and substituting in this equation the known values of a and b,

$$C\,F = \tfrac{7}{4}\,l^2\sqrt{2}\sqrt{\left(\frac{1 + \tan^2\varphi}{\frac{49}{16}l^2 + 2\,l^2\tan^2\varphi}\right)}$$

$$= \tfrac{7}{4}\,l^2\sqrt{\left(\frac{2 + 2\tan^2\varphi}{l^2\left(\frac{49}{16} + 2\tan^2\varphi\right)}\right)}$$

$$= \tfrac{7}{4}\,l\sqrt{\left(\frac{1 + \tan^2\varphi}{\frac{49}{32} + \tan^2\varphi}\right)}.$$

NOTE IV.

Great difference of opinion has existed among miners as to what should be the charge for a globe of compression. The following method of considering this subject appears to be as little open to objection as any other that has yet been devised.

One of the globes of compression at the siege of Schweidnitz was charged with 5404 lbs. of powder, which being placed under a line of least resistance of 16 feet, produced a crater of 41½ feet radius.

Let us suppose that the globe of compression in question was exploded in common earth, and ascertain under what line of least resistance the same charge of 5404 lbs. must be placed in order to produce the effect of a common mine, viz. a crater of a radius equal to the length of the line of least resistance. Now, as the charges of common mines are in propor-

tion to the cubes of their lines of least resistance, we have

$$110 \text{ lbs.} : 10^3 :: 5404 \text{ lbs.} : 49127 \cdot 27;$$

and, extracting the root, we find 36·62 or 36 ft. 7 in. to be the line of least resistance sought.

In Fig. 131 are represented the effects of the globe of compression exploded at Schweidnitz, and of a common mine under the same line of least resistance, their difference being divided into three equal parts; and also the crater of a common mine under a similar line of least resistance, viz. 16 feet, and under the line of least resistance corresponding to the charge of 5404 lbs.; the difference between these two craters being, in like manner, divided into three equal parts.

It appears evident, that if under a line of least resistance of 16 feet we wish to produce craters of the radii A B, A C, we must use the charges corresponding to the lines of least resistance *a b* and *a c*.

From the above reasoning it follows, that a rule to find the charge for a globe of compression may be thus determined:—

Subtract the given line of least resistance (16 feet) from the radius of the crater of the globe of compression ($41\frac{1}{2}$ feet), and also from the line of least resistance of the common mine requiring the same charge (36 ft. 7 in.); divide the latter difference by the former: we then have $\frac{20 \text{ ft. } 7 \text{ in.}}{25 \text{ ft. } 6 \text{ in.}}$ or, $\frac{20 \cdot 583}{20 \cdot 5} = \cdot 8071$; of which quotient the last figures may be neglected. The rule, therefore, is, to "subtract the given line of least resistance from the radius of the crater to be produced; multiply the difference by ·8; and the product, added to the given line of least resistance, gives the line of least resistance of a common mine requiring the same

charge as the globe of compression." This rule larger charges for the other globes of compre exploded at Schweidnitz than were actually used; charges deduced from it are also greater than found by Marescot's more complex rule: the e therefore, if there be any, lies on the right side.

THE END.

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